SCIENCE

AEROSPACE ENGINEERING

Serial Dept.
SEP

New Publishing Program

Editorial . . . . page 15

SEPTEMBER / 1960

When crews of SAC's 1st Missile Division successfully launched the USAF ICBM Atlas from Vandenberg Air Force Base, September 9, 1959, the world became aware that the United States had brought into being a formidable retaliatory power for peace. Within four months after the first operational launch, the Air Force doubly underlined this missile's capability. On a single day, January 26, 1960, the 16th and 17th consecutive successful Atlases were fired intercontinental ranges to predetermined targets from both Atlantic and Pacific bases.

After only five years of intensive development, including concurrent research, testing and fabrication under this nation's top military priority, Atlas is extremely versatile as well as powerful. It was the Project Score satellite vehicle and is scheduled for use in Project Mercury, the Man in Space Program, and in other space exploration missions. Thus, used as a booster for space projects, Atlas provides the nation with a key capability in scientific as well as military applications.

Space Technology Laboratories provides the systems engineering and technical direction for the Atlas as well as other portions of the Air Force Ballistic Missile Program. Much of what was learned in building Atlas has helped cut the lead-time in the development of such other Air Force Ballistic Missiles as Thor, Titan and Minuteman.

Among the industrial organizations which have worked in concert in developing Atlas are such major contractors as: Convair, Division of General Dynamics Corp. for airframe, assembly and test; General Electric Co. and Burroughs Corp. for radio guidance; Arma, Division of American Bosch and Arma Corp. for inertial guidance; Rocketdyne Division of North American Aviation, Inc., for propulsion; General Electric Co. for re-entry vehicle; Acoustica Associates for propellant utilization.

America's first intercontinental ballistic missile...is helping to bear the burden of today's power for peace

ATLAS

The continuing development of Atlas as well as other USAF missiles and related space probes, has created important positions on STL's technical staff for scientists and engineers with outstanding capabilities in: thermodynamics, aerodynamics, electronics, propulsion systems, structures, physics, computer technology, telemetry, and instrumentation. If you believe you can contribute in these or related fields and disciplines, you are invited to send your resume to:

SPACE TECHNOLOGY LABORATORIES, INC.

P. O. Box 95004, Los Angeles 45, California • STL Florida offers immediate opportunities to outstanding Project Engineers—Support Equipment. Write: Mr. George S. Cherniak, STL, P. O. Box 4277, Patrick Air Force Base, Florida

AEROSPACE ENGINEERING

"The prestige magazine of the Aerospace Industry"

VOLUME 19 / NUMBER 9 **September 1960**

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Wyman-Gordon makes a major
Now parts are being forged in

Nickel-base
high-temperature alloy
45" diameter
520 pounds

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- Aluminum and Magnesium

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143 pounds

PHYSICAL PROPERTIES

	ALLOY*	TEST TEMPERATURE °F.	HEAT TREAT	GUARANTEED MINIMUM ULTIMATE TENSILE STRENGTH PSI	GUARANTEED MINIMUM 0.2% YIELD STRENGTH PSI	GUARANTEED MINIMUM ELONGATION %	TYPICAL VALUES ULTIMATE TENSILE STRENGTH PSI	TYPICAL VALUES 0.2% YIELD STRENGTH PSI	TYPICAL VALUES ELONGATION %
TENSILE AND YIELD STRENGTHS	Waspaloy	RT	A	175,000	120,000	15.0	194,000	136,000	24.0
		1000	A	162,000	112,000	13.0	175,000	124,000	23.0
	René 41	RT	B	180,000	132,000	12.0	200,000	150,000	15.0
		1400	B	135,000	115,000	13.0	145,000	125,000	18.0
	Astroloy	RT	C	190,000	138,000	10.0	205,000	152,000	12.0
		1400	C	150,000	122,000	12.0	160,000	132,000	15.0
	U-500	RT	D	175,000	120,000	10.0	195,000	135,000	12.0
		1400	D	125,000	105,000	12.0	140,000	120,000	15.0
	M-252	RT	B	170,000	115,000	15.0	185,000	125,000	20.0
		1000	B	160,000	105,000	15.0	165,000	115,000	22.0

	ALLOY*	TEMPERATURE STRESS	GUARANTEED MINIMUM	TYPICAL VALUES
STRESS RUPTURE	Waspaloy	1350°F.—70,000 psi	70 hours—6% Elongation	130 hours—16% Elongation
	René 41	1350°F.—85,000 psi	30 hours—8% Elongation	60 hours—15% Elongation
	Astroloy	1800°F.—20,000 psi	20 hours—7% Elongation	35 hours—12% Elongation
	Udimet 500	1650°F.—25,000 psi	30 hours—6% Elongation	55 hours—12% Elongation
	M-252	1500°F.—40,000 psi	30 hours—8% Elongation	55 hours—16% Elongation

NOTE: The guaranteed minimums are based upon radial and tangential test locations.

COMPOSITION AND HEAT TREATMENT

	ALLOY*	ELEMENTS C	Cr	Mo	Co	Ti	Al	B	Ni
CHEMISTRY	Waspaloy	.08	19.0	4.3	13.5	3.0	1.4	.004	Balance
	René 41	.08	19.0	10.0	11.0	3.1	1.6	.004	Balance
	Astroloy	.05	15.0	5.0	15.0	3.5	4.3	.030	Balance
	Udimet 500	.07	18.5	5.0	18.3	3.0	3.0	.003	Balance
	M-252	.15	20.0	10.0	10.0	3.0	1.3	.002	Balance

HEAT TREATMENT	A.	1850°F.—4 hours—OQ; 1550°F.—2 hours—AC; 1400°F.—16 hours—AC
	B.	1950°F.—4 hours—AC; 1400°F.—16 hours—AC
	C.	2100°F.—½ hour—AC; 1400°F.—16 hours—AC
	D.	1975°F.—4 hours—AC; 1500°F.—24 hours—AC; 1400°F.—16 hours—AC

NOTE: Refer to appropriate heat treat code in Tensile & Yield Strength table.

*Waspaloy: Pratt & Whitney Aircraft Corp.; René 41, Astroloy and M-252: General Electric Company; Udimet 500: Metals Division, Kelsey-Hayes Company.

IAS News

. . . a record of people and events of interest to Institute Members

Cosponsored Hypervelocity Meeting Planned for Denver Next Month

Trip to Test Facility to Precede Sessions

A NATIONAL SYMPOSIUM on Hypervelocity Techniques, cosponsored by the IAS and the Denver Research Institute (DRI) of the University of Denver, is scheduled for October 20–21 at the Shirley-Savoy Hotel in Denver, Colo. Plans for the meeting include five technical sessions, a field trip, a luncheon, and a banquet.

The committee, made up of representatives of DRI and the Denver Section of the IAS, is headed by Co-chairmen W. G. Harrach of DRI's Mechanics Division, and Laurence R. Soderberg, Principal Engineer, Unit Head, Advanced Design Aerodynamics, The Martin Company-Denver, representing the IAS.

On the afternoon of Wednesday, October 19, one day preceding official opening of the symposium, meeting attendees will visit Martin's Manufacturing and Test Facilities where they will be briefed on the Titan weapon system. On the following day, a luncheon will be addressed by Major Gen. W. S. Stone, Superintendent of the United States Air Force Academy. The speaker for the banquet to be held that same evening will be announced at a later date.

A book of proceedings composed of papers to be presented at the meeting is planned for publication in time for the symposium. Broadsides giving more complete details and reservation cards will be mailed to members later this month.

Technical sessions are scheduled as follows:

Thursday, October 20

8:30 a.m.—Hypervelocity Projection Techniques

Chairman: A. C. Charters, Chief, Hypervelocity Ballistics Range Br., Ames Research Center, NASA.

"Some Historical Highlights of Hypervelocity Research" by J. S. Rinehart, Colorado School of Mines; "Proposed Method of Light Gas Gun Design and Operating Procedure" by D. O. Francis, Leesona Corp; "Acceleration of Spherical Projectiles to Hypervelocity by Aerodynamic Drag in a Dense Flowing Plasma" by C. N. Scully and D. L. Cowan, Aero-Space Labs., Missile Div., North American Aviation, Inc.; "Electroballistic Accelerator Techniques" by H. F. Swift, U.S. Naval Research Labs.; and "Ballistic Range Developments" by J. Eckerman, W. McKay, R. Ouellette, R. Schweiger, and G. Theophanis, AVCO R&D Div.

1:15 p.m.—Hypervelocity Projection Techniques

Chairman to be announced.

"Sequential Electric Discharge Light Gas Gun" by V. F. Volpe and F. J. Zimmerman, Armour Research Foundation, Illinois Institute of Technology; "A Multistage Shaped Charge Projection Technique" by M. W. Burnham, DRI, Univ. of Denver; "Construction of a High-Pressure, High-Temperature, Light Gas Gun" by W. S. Brown, W. A. Boyd, Emerson Cannon, and W. S. Partridge, Utah R&D Co., Inc.; "Theory of a Hypervelocity Electromagnetic Mass Accelerator" by Karlheinz Thom, Langley Res. Center, NASA; and a panel discussion moderated by T. C. Poulter, Director, Poulter Research Labs., Stanford Research Institute.

L. R. Soderberg
Symposium Cochairman

W. G. Harrach
Symposium Cochairman

Friday, October 21

8:45 a.m.—Projection Techniques and Instrumentation

Chairman to be announced.

"High-Density Storage of Electrostatic Energy" by E. T. Benedikt and R. Lepper, Space Physics Lab., Astro Systems and Research Labs., Northrop Corp.; "Development of Telemetry for a Hypervelocity Range" by M. K. Kingery and P. L. Clemens, ARO, Inc.; "A Hypervelocity Precision Impact Instrument" by W. A. Allen, G. E. Meloy, and J. W. Rogers, Michelson Lab., U.S. Naval Ordnance Test Station; "Observations of Metallic Projectile Impacts of Small Particles at Velocities Ranging from 5,000 ft./sec. to 7,500 ft./sec." by J. P. McDonough and E. N. Hegge, Watertown Arsenal; and "The Relative Merits of Various Test Facilities With Regard to Simulation of Hypersonic Ablation Phenomena" by Steven Georgriev, AVCO-Everett Res. Lab.

(*Continued on page 10*)

Seventeen First Prizes Awarded at Regional Student Conferences

Paper Competition, Field Trips, Banquets, Featured at Gatherings in Seven Cities

A RECORD 122 technical papers was the highlight of the seven IAS Regional Student Conferences held throughout the United States this spring. Seventeen of these papers, first-prize winners in graduate and undergraduate divisions from all seven conferences, are now eligible for judging for the two Minta Martin National Awards, one in each division, to be presented at the Institute's 29th Annual Meeting in January.

This year's conferences were held in Los Angeles, Brooklyn, Dallas, St. Louis, Morgantown (W. Va.), Atlanta, and Detroit. The conferences and cash awards are sponsored annually by the Minta Martin Aeronautical Student Fund, established by the late Glenn L. Martin in honor of his mother.

West Coast Conference

Activities including an industry-faculty meeting; a luncheon address by A. Scott Crossfield, Chief Test Pilot of North American Aviation; the Minta Martin Dinner address by Brig. Gen. Benjamin S. Kelsey, USAF (Ret.), now Hunsaker Professor of Aeronautical Engineering at M.I.T.; a field trip to Lockheed; and the Awards Banquet featuring Jim Reichert, Chief Test Pilot of Doak Aircraft Co., Inc., were arranged for this conference under the sponsorship of the Institute's Los Angeles Section and the Student Branch at California Institute of Technology.

With a total of 14 papers presented, awards were made as follows: in the *Doctorate Division*, first place went to Roddam Narasimha, and second place to R. J. Arenz, both of California Institute of Technology. First place in the *Master's Division* was awarded to Roy S. Hickman, University of California at Berkeley; second place to Thomas L. Vincent, University of Arizona; and third place to Gary A. Flandro of Caltech. *Undergraduate Division* first place was won by Jere A. Anderson, University of Washington; second place by Richard H. Koury, California State Polytechnic College; and third place by Charles Sinclair, University of California at Berkeley.

Northeastern Conference

With the IAS Student Branch of Polytechnic Institute of Brooklyn serving as hosts, the Northeastern Conference heard a total of 22 papers. The Awards Banquet was addressed by Dr. Alexander H. Flax, Chief Scientist, USAF. Awards were presented by Institute Director S. Paul Johnston.

Doctorate Division first place was awarded to Atle Gjelsvik of Brown University, second place to Thomas Lardner, and third place to Martin H. Steiger, both of Brooklyn Poly. First place in the *Master's Division* went to Imants Reba of Brooklyn Poly, second place to Richard V. Monopolis of Brown University, and third place to Bengt Sonnerup of Cornell University. In the *Undergraduate Division*, first place was awarded to Herbert Fox of M.I.T., second and third places, respectively, to Roger M. T. Fischler and Stanley Nathanson of Brooklyn Poly.

Southwestern Conference

Sponsored by the Institute's Texas Section, the Southwestern Conference featured luncheon addresses by E. V. Marshall, Project Manager of Dyna-Soar, Chance Vought Aircraft's Astronautics Division; Bartram Kelley, Vice-President—Engineering for Bell Helicopter Corp.; Howard Marx, Manager of Development Planning, Temco Aircraft Corp.; and E. L. Secrest, Chief of Applied Research, Advanced Design Section of Convair-Ft. Worth. Joseph A. Walker, NASA's X-15 Test Pilot, spoke before a specialists' meeting, and J. R. Clark, General Manager of Chance Vought's Astronautics Division, addressed the Awards Banquet. IAS President Donald L. Putt, President of United Technology Corp., presented the awards. An additional feature was a field trip to several aircraft plants.

With 15 papers submitted, awards were made in the *Master's Division* for a first-place tie between David L. Kohlman of the University of Kansas, and David A. Pirie and George W. Stone of Georgia Institute of Technology. Third place was awarded to Herbert E. Smith of the University of Oklahoma. In the *Undergraduate Division*, Arnold E. Ebneter of Texas A&M won first place, James H. Seely of the University of Colorado won second, and John R. Johnston of the University of Wichita was awarded third.

St. Louis Conference

A total of 32 papers was submitted at this conference, which was sponsored by the St. Louis Section. Also featured was a tour of McDonnell Aircraft Corporation's production line, including the Mercury capsule assembly. The Awards Banquet speaker was Col. Gerhardt C. Clementson, Head of the Department of Aerodynamics at the U.S. Air Force Academy. Awards, presented by Conference Chairman H. C. Rechtien, Jr., and Section Chairman William J. Blatz, were presented in the *Master's Division* to John W. Steurer of

(Left) Jerome Lederer speaks on "Air Safety and the Engineer" at Middle Atlantic Student Conference Banquet. (Center) Professor John Hoover, Student Branch Faculty Adviser at the University of Florida, chats with Eastern Region Vice-President Charles Tilgner, Jr. (center) and award winner Samuel Gulkis (right) at Southeastern Student Conference. (Right) Brooklyn Poly Student Branch Chairman Gerald Roffe opens proceedings of Northeastern Conference.

the University of Notre Dame, first place, and to Arthur L. Seward of Purdue University, second place. *Undergraduate Division* first, second, and third prizes, respectively, were presented to R. E. Brown of the University of Wichita, to Dennis Wai-Man Tsao of St. Louis University's Parks College, and to Gerard Wayne DeLong of the University of Kansas. Given Honorable Mention were Costas J. Choliasmenos, Gary Martin Korb, and William F. Lawrence, all of the University of Kansas.

Middle Atlantic Conference

The Student Branch at West Virginia University served as host for this 2-day conference in which 19 papers were presented. Featured speaker at the banquet was Jerome Lederer, Director of the Cornell-Guggenheim Aviation Safety Center and the Flight Safety Foundation. Awards were presented in the *Doctorate Division* to J. N. Perkins of Virginia Polytechnic Institute, in the *Master's Division* to A. J. Russo, V.P.I., and in the *Undergraduate Division* to J. O. Bunting, first place, to G. W. Hall, second place, and to D. L. Henderson, third place, all of the University of Virginia. Edward A. Patterson of West Virginia University received Honorable Mention.

Southeastern Conference

The Atlanta Section of the IAS sponsored this meeting, while the University of Kentucky Student Branch was host. Speaker at the luncheon was Brig. Gen. W. H. Wise, Commander of the 32nd Air Division SAGE. Field trips to local industry were followed by the Awards Banquet, addressed by Edward R. Sharp, Director, Lewis Research Center, NASA. Awards, from a total of twelve papers submitted, were presented by IAS Eastern Region Vice-President Charles Tilgner, Jr.

The *Master's Award* was won by William G. Wells of Mississippi State University; in the *Undergraduate Division*, first place was won by John W. Gresham, Jr., and Thomas P. Tytula of Auburn University. Tied for second place were Samuel Gulkis of the University of Florida, and David L. Murphree of Mississippi State. Third place was won by John J. Banchetti of Georgia Tech.

Detroit Conference

Sponsored by the Detroit Section and the Wayne State University Student Branch, this conference heard a total of eight papers. *Undergraduate Awards* were given to Charles R. Meldrum, University of Detroit, first place; Neil V. Loving, Wayne State, second place; and Jerry Jenkins, University of Cincinnati, third place.

Award winners and Student Branch Faculty Advisers at the St. Louis Conference. *Front row, left to right,* Prof. Ammon S. Andes (Kansas University), and Dennis Wai-Man Tsao, Gerard Wayne DeLong, and Prof. Paul E. Stanley (Purdue). *Second row,* John W. Steurer, Arthur L. Seward, and Prof. Richard Andres (Parks College). Richard E. Brown was not present for the picture.

Judges, *in foreground from left,* W. Wai Chao of Vickers, Inc., C. C. Gage of Chrysler Missile Div., and E. Agni, Curtiss-Wright Corp., discuss merits of papers presented at Detroit Student Conference.

Southwestern Conference award winners line up. *Left to right* are David A. Pirie, George W. Stone, John R. Johnston, James H. Seely, Arnold E. Ebneter, and David L. Kohlman.

West Coast Conference first place winner in the Doctorate Division, Roddam Narasimha, holds trophy presented by IAS Western Region Vice-President Harold T. Luskin, *center.* Conference Chairman E. R. Van Driest is at right.

Continued from page 7

8:45 a.m.—Hypervelocity Tunnels

Chairman: Eugene S. Love, Asst. Chief, Aerophysics Div., Langley Research Center, NASA.

"A study of the Overall Problems of a Hypervelocity Tunnel Having Continuous Operation" by G. M. Palmer, Purdue Univ.; "Development of Capacity- and Inductance-Driven Hotshot Tunnels" by J. Lukasiewicz and J. P. von der Bliek, ARO, Inc., and W. G. Harris and R. M. Miller, Wind Tunnel Lab., Boeing Airplane Co.; "Seven Megajoule Arc Driven Hypervelocity Wind Tunnel" by R. E. Rohtert and K. R. Sivier, Gas Dynamics Lab., McDonnell Aircraft Corp.; "Development of a Hotshot Arc Chamber for Long Component Life and Low Gas Contamination" by J. B. Kyser, Hypervelocity Wind Tunnel, Chance Vought Aircraft, Inc.; and "Force, Pressure, and Heat-Transfer Instrumentation for Hotshot Tunnels" by W. T. Earhart and D. S. Bynum, ARO, Inc.

1:15 p.m.—Hypervelocity Tunnels

Chairman: Alan Pope, Chairman, Supersonic Wind Tunnel Assn.

"High-Speed Flow Experiment Using Solid Propellant Combustion Gases" by H. A. Wallskog, Applied Physics Lab., The Johns Hopkins Univ.; "Performance Characteristics of a Chambered-Buffered Shock Tube" by S. G. Chapin and R. H. Heyman, Martin-Denver; "Studying Hypersonic Flight in the Shock Tunnel" by C. E. Wittliff, Aerodynamic Res. Dept., Cornell Aeronautical Lab., Inc.; "Recent Work in the Development of Hypersonic Helium Tunnels" by Arthur Henderson, Jr., and D. L. Baradell, Langley Research Center, NASA; and a panel discussion.

Grover Loening Named for Guggenheim Medal

Grover Loening, IAS Fellow, Benefactor, and Founding Member, has been designated the Daniel Guggenheim Medal recipient for 1960. The award will be presented at the Institute's Honors Night Dinner this coming January. Mr. Loening's selection is for "Pioneer, Engineer, Public Servant—for a lifetime devoted to the advancement of aeronautics in America."

The medal, given annually for notable achievement in the advancement of aeronautics, is administered by a Board of Award consisting of previous recipients of the medal living within the United States, and persons designated by the American Society of Mechanical Engineers, the Society of Automotive Engineers, and the Institute of the Aeronautical Sciences. In addition, there are a number of foreign members chosen by the Board itself. Provision for the medal was made in 1928 by a gift from the Daniel Guggenheim Fund for the promotion of Aeronautics.

Mr. Loening's career includes many notable firsts. He was the first aeronautical engineer employed by Orville Wright and by the Army; he presented one of the first theses on aeronautics in an American university while at Columbia; and he was the first president of the Aeronautical Chamber of Commerce. He was among the founders of Pan American Airways and of Grumman Aircraft Engineering Corp. In 1959 he presented the first Lester D. Gardner Lecture at Massachusetts Institute of Technology.

Today Mr. Loening is a Director of the Flight Safety Foundation, New York Airways, and Fairchild Engine and Airplane Co., a member of the Advisory Board of the National Air Museum, and a consultant to the Navy and Air Force as well as Curtiss-Wright Corp.

A member of the SAE and a Fellow of the Royal Aeronautical Society, Mr. Loening holds the Collier Trophy (1921), the Legion of Merit (1948), the Egleston Medal (1950), the Wright Brothers Trophy (1952), and the Air Force Medal (1955).

Necrology

John P. V. Heinmuller

John P. V. Heinmuller, President and Director of the Longines-Wittnauer Watch Company and IAS Benefactor, died at his home in New York City on July 11. He was 68 years of age.

An enthusiastic collector of airmail stamps and flight covers, Mr. Heinmuller accumulated one of the most notable collections in the world. His various albums received numerous philatelic prizes. Mr. Heinmuller presented these rare and priceless collections to the IAS over a period of years.

Mr. Heinmuller helped organize the Timing Contest Board of the National Aeronautic Association, and as Chief Timer of the Fédération Aéronautique Internationale timed such outstanding flyers as Charles Lindbergh, Clarence Chamberlin, Wiley Post, and Amelia Earhart.

Capt. Richard S. Beyer, USAF (A)
April, 1960, Springfield, Vt.

Littlewood IAS Representative on Research Council

William Littlewood (HF), Vice-President, Equipment Research for American Airlines, Inc., and IAS President for 1959, has been appointed to represent the Institute as a member of the National Research Council and its Division of Engineering and Industrial Research for a three-year term. He succeeds Dr. Theodore P. Wright (HF), recently retired as Vice-President of Cornell University in charge of the administration of sponsored research. Mr. Littlewood's appointment was effective July 1.

ASEE Honors Three Educators

Three of the nation's highest awards in engineering education were presented to IAS members by the American Society for Engineering Education at its annual banquet at Purdue University on June 23. The awards, presented by ASEE President B. Richard Teare, Jr., were made as follows:

Dr. Theodore von Kármán, HF, Chairman of AGARD of NATO, received the Lamme Medal for distinguished contributions to engineering education and research. Dr. von Kármán was cited "for his outstanding, creative, and inspiring teaching; for his unique leadership in and creative influence on engineering education; and for his active leadership toward international cooperation in science and engineering."

Dr. Maurice J. Zucrow, AF, Atkins Professor of Engineering at Purdue University, received the Vincent Bendix

In October—

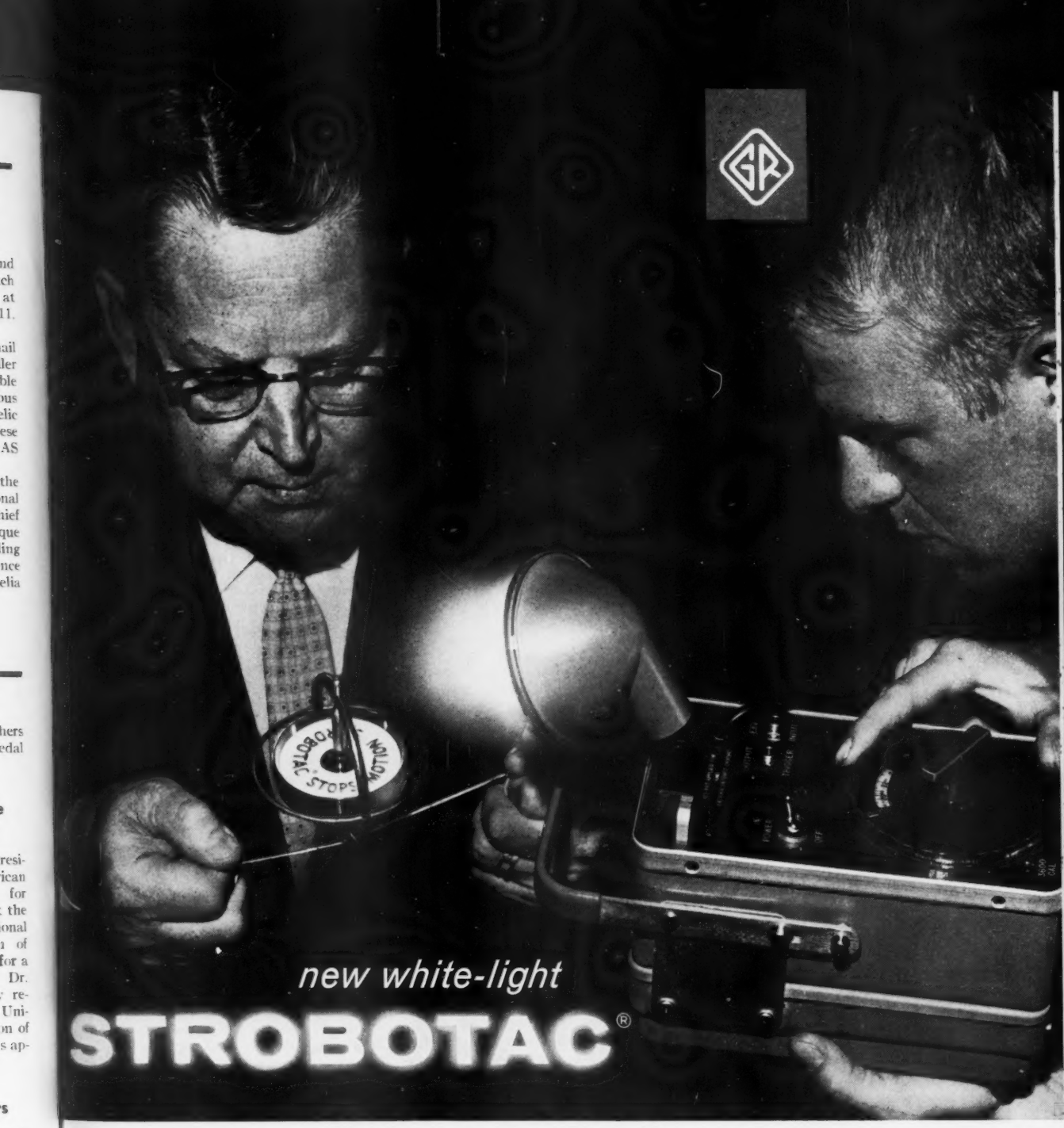
A BETTER AND BIGGER AEROSPACE ENGINEERING

While several separate reports on changes in *Aerospace Engineering* have appeared, it is felt that readers might welcome a résumé of what to expect next month.

The magazine will become, in accordance with recommendations approved by the IAS Council, exclusively technical. Eight reports will fill our technical articles section, covering the Trajectory Problem, Materials, Electronics, Re-Entry, Life in Space, Guidance-Control, Air Transportation, as well as Propulsion Systems. These full-length articles almost double the number appearing in this month's issue . . . a comprehensive collection which has been made possible in part by removal of all news matter from *Aerospace Engineering* as also approved by the Council.

News of the Institute henceforth will appear in a separate publication, *IAS News*, which will be published for the first time on the 15th of this month and should reach members soon thereafter. New deadlines for *IAS News* have been provided to Sections by IAS Assistant Secretary Thomas Meskel.

For further information on this "New Publishing Program," see the Editorial, page 15.



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Award for outstanding research contributions. The award cited Dr. Zucrow "for his exploitation of basic research in the field of jet propulsion; for his genius in stimulating and disciplining the creative endeavors of young research engineers; and for his participation in affairs that are vital to the competitive strength of the nation."

Dr. Ali B. Cambel, M, Chairman of Northwestern University's Mechanical Engineering Department, was awarded the Curtis W. McGraw Award for research contributions by a young engineering teacher, specifically for originating new concepts and methods in a research program in aerothermochemistry, magnetohydrodynamics, and plasma physics.

Duncan B. Gardiner (M), formerly Director of Research and Development, has been appointed Manager, Corporate Engineering, for Vickers Incorporated.

News of Members

Major Gen. Victor E. Bertrandias, USAF (Ret.) (A), recently elected to the Board of Directors of Transval Electronics Corp., was incorrectly listed as Vice-President in charge of Sales for Douglas Aircraft Co. in the June issue of *A/SE*. General Bertrandias is an Engineering Consultant.

James V. Bitner, Jr. (M), formerly Technical Director in charge of engineering of the Mace B program for the Martin Co., has joined Lear, Inc., as Assistant General Manager of the Instrument Division.

Robert C. Boe (M) has been appointed Marketing Manager of the Buffalo Operations of Sylvania Electronic Systems, a division of Sylvania Electric Products Inc. Prior to joining Sylvania, Mr. Boe was Marketing Manager and Assistant to the Vice-President and General Manager of the Cook Technological Center.

Doane R. Gero (AF) has been appointed President of Information Systems, Inc. Prior to joining I.S.I., Mr. Gero was Corporate Vice-President and General Sales Manager for Giannini Controls Corp.

G. F. Bremer (M), formerly Manager of Military Requirements in the Indianapolis office of General Motors' Allison Division, has been transferred to the Dayton Zone Office as Manager.

Capt. Thomas Walter Collins, Jr., USN (AF), Bureau of Aeronautics Representative in St. Louis since July, 1957, retired from the Navy on June 30.

Frank W. Davis (AF), Convair-Ft. Worth Manager and corporate Vice-President, was awarded the honorary degree of Doctor of Science by West Virginia University.

James H. Fisher (M) has been named a Vice-President of Electro-Optical Systems, Inc., with repsonsibility for Advance Planning. In addition to his new duties, Dr. Fisher will continue as Manager of the Energy Research Division.

Bernhard H. Goethert (AF) has been appointed a member of the Fluid Dynamics Panel in NATO's Advisory Group for Aeronautical Research and Development (AGARD). Dr. Goethert is Director of Engineering for ARO, Inc., contract operator for the Air Force's Arnold Engineering Development Center.

Capt. John Jay Ide, USNR (F) has been awarded the cross of Chevalier of the Legion of Honor by the French Government. For twenty years Captain Ide was stationed at the American Embassy in Paris as European Representative of NACA. For the last year he has been President of the Federation of French Alliances in the United States and is currently Vice-President of the Fédération Aéronautique Internationale.

Charles S. Jones (AF), President of the Academy of Aeronautics, LaGuardia Airport, has retired from the Executive Committee of the Technical Institute Division of the American Society for Engineering Education. Dr. Jones has served on the Committee since the establishment of the Technical Institute Division. **Dr. Walter M. Hartung** (AF), Dean of the Academy of Aeronautics, succeeds Dr. Jones on the Committee.

Miles C. Leverett (AF) has been named President of the American Nuclear Society for 1960–1961. Dr. Leverett is Manager of Development Labs. for the G-E Aircraft Nuclear Propulsion Dept.

Arnold M. Levine (M), Vice-President of International Telephone and Telegraph Laboratories, Inc., was awarded the honorary degree of Doctor of Science by Tri-State College, Angola, Indiana, on June 16. During the presentation of the degree, Mr. Levine was praised as being "among the leading scientists of the free world . . . his scientific acumen contributes immeasurably to staying the hand of world-wide totalitarian dominion. The leadership which has resulted in the rapid and steady growth of his missile and space systems laboratory was due as much to his technical knowledge as to his business acumen."

Dale A. Lichty (A) has been elected Vice-President in charge of the Systems & Controls Group of Crane Co. Mr. Lichty was formerly Head of Hydro-Aire, Inc., a division of Crane Co.

Frank E. Mamrol (M) has been appointed Chief Engineer of Piasecki Aircraft Corp. Mr. Mamrol was formerly Chief of Design and Chief Project Engineer for Piasecki.

Roy E. Marquardt (F), President of Marquardt Corp., has been elected to the Board of Directors of Systron-Donner Corp.

Robert E. Pendley (AF) has been appointed Assistant Chief, Power Plant Section, El Segundo Division of Douglas Aircraft Co., Inc. Mr. Pendley was formerly Supervisor, Aero-Thermo Group.

Thomas L. Phillips (AF) has been appointed Assistant General Manager of the Raytheon Company's Missile Systems Division. Mr. Phillips was formerly Manager of the division's Bedford Labs.

Verl Smith, Jr. (M) has been appointed General Manager of the Rushmont Corp. Prior to joining Rushmont, Mr. Smith was Assistant to the Vice-President of Engineering for the Northrop Corp.

Thomas L. K. Smull (AF), formerly Assistant Chief of NASA's Research Grants and Contracts Office, has been appointed Director of the office. The office, formerly a part of the Office of Advanced Research Programs, has been transferred to the Office of Business Administration.

Herbert G. Somerson (M) has been appointed Manager, Advance Re-Entry Vehicle Engineering Operation, Missile and Space Vehicle Dept., General Electric Co. Mr. Somerson was previously Systems Project Engineer at MSVD.

Vice-Adm. Selden B. Spangler, Jr., USN (Ret.) (M), Director of Research for The Garrett Corp., has been named a member of the Visiting Committee for the Massachusetts Institute of Technology.

George Starbird (M), President of Meletron Corp., has been elected to a 3-year term on the Board of Directors of the Strategic Industries Association.

(*Continued on page 48*)

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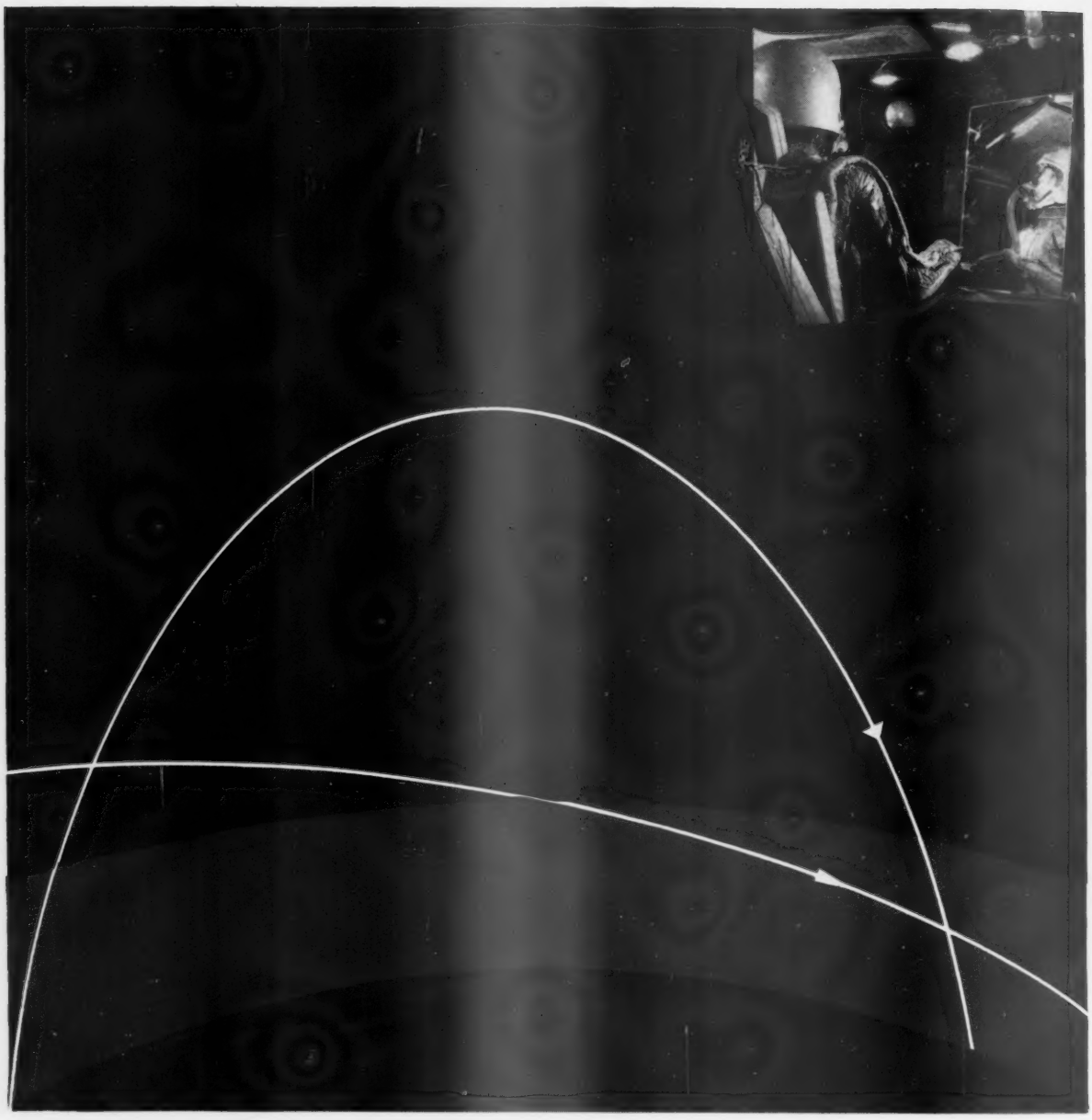

Ballistic and boost-glide flight paths

These flight paths, arcing through space and re-entering the atmosphere, are characteristic of the paths of a ballistic missile and a boost-glide vehicle. In both areas, Boeing holds major contract responsibilities. Boeing is weapon system integrator for the solid-fuel ICBM, Minuteman, and as part of a USAF-NASA research program, is developing Dyna-Soar to study the problems of manned space flight. The Dyna-Soar vehicle will be capable of re-entering the atmosphere and making a normal controlled landing.

Boeing scientists and engineers, in addition, are advancing the state of the art in many areas: advanced military and commercial aircraft, hypersonic flight, space crew environments, vertical and short take-off and landing aircraft, gas turbine engines, anti-submarine warfare systems, among others.

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EDITORIAL

New Publishing Program

Several months ago announcement was made of the adoption by the IAS Council of a revised plan for IAS publications recommended by the National Publications Policy Committee (see Editorial, June, 1960). The Program called for expansion of the technical and engineering content of AEROSPACE ENGINEERING by eliminating certain sections of the magazine—substituting therefor additional feature articles on subjects of major interest to the membership. Under the plan, "IAS News" and "Abstracts and Reviews" are to be published and distributed separately—the News in the form of a monthly newsletter sent without charge to every member, and the Abstracts as a service available at extra charge to those who wish to subscribe.

The new program was evolved after a detailed analysis of the wishes of the IAS membership as disclosed by "reader" and "professional interest" surveys conducted during the past 2 years. These studies gave clear indication that:

(1) Practically all readers wanted more "feature" type technical articles in their areas of professional interest ("an engineering publication comparable in scope and in stature with the IAS JOURNAL").

(2) Most IAS members wanted condensed, easy-to-read, up-to-date coverage of IAS events and programs ("an expanded Green Sheet").

(3) Relatively few readers (about 10 per cent) indicated acute interest in the Abstracts Section ("these pages could be put to better use"), but those who did use it regularly needed it badly ("an indispensable professional tool").

These conclusions provided the basis for the Publications Policy Committee's recommendation.

We are now taking the first step toward implementation. Beginning with the October issue of AEROSPACE ENGINEERING, the IAS News section will be eliminated, and the feature sections of the magazine "fattened" by the inclusion of several carefully selected technical papers. For the time being—for reasons outlined below—the Abstracts and Reviews remain in the book. This arrangement will continue for the balance of the current year.

On September 15, the first issue of the monthly newsletter, "IAS News," will be mailed. Its initial format is somewhat experimental and will be subject to improvement as time goes on. Its purpose is to keep all Institute members informed of current and future IAS events. It will be used as a vehicle to distribute meeting notices and advance programs which were formerly mailed as separate items. All members are urged to leaf through each issue carefully so that no announcements of importance will be missed.

How soon we can effect the complete separation of the Abstracts Section depends to a certain extent upon a negotiation that is now under way with the National Science Foundation. We have applied for a grant to assist in the development of an augmented abstracting program, but, to date, the matter is still pending. We hope, however, that in one way or another, we can begin the publication of a separate subscription-type abstract and review service by the first of the coming year.

Meanwhile, our editors have been given a "go-ahead" for a materially expanded feature section. Working closely with IAS Technical Advisory people, they are laying out the engineering content of each issue for a period of 3 to 6 months ahead so that IAS members may be given the kind and quality of professional support that they need from a publication of this type in this rapidly changing aerospace age.

—SPJ

The technique of dynamic programing has been used to determine optimum flight profiles for interceptor aircraft. A further development of this method has resulted in a ground-based computer program which outputs a printed graphical presentation of the families of optimum flight profiles. This visual display performs a variety of functions, particularly those involving the problems of selecting general flight control laws and logic to be designed into airborne flight control computers. Typical tactical situations are presented and analyzed.

Graphic Presentation of Optimum Flight Profiles

Donald W. Richardson, AFIAS, *Hughes Aircraft Company*

Mr. Richardson has been a member of the technical staff of Hughes since 1957 and is Head, Aircraft Performance Analysis Group, Digital Systems Department, Research and Development Laboratories. Formerly associated as an aerodynamics engineer with Hiller Helicopters, Curtiss-Wright Propeller Division, and Chase Aircraft, his current assignment includes project responsibility for Hughes commercial navigation control systems. He was graduated with a B.S. degree in aeronautical engineering from Georgia Tech in 1950, and obtained his M.S. degree from the Newark College of Engineering in 1958.

IN THE COURSE of programing mission profiles (speed vs. altitude) for interceptor aircraft fire control systems, the resulting speed-altitude schedules and logic are usually compromises based on practical control considerations and necessary simplifications, as well as on tactical necessities. The problem of analytically determining an optimum, or even reasonably efficient, mission profile has for many years been a source of considerable discomfort and man-hour consumption for the aerodynamics engineer. Application of the technique of dynamic programing[1] as an approximate solution to this problem has resulted in acceptable profiles which sufficiently approach true optimum paths for the purpose of programing these paths in an airborne computer-control system. By optimum climb path, for example, the writer means the transfer of the aircraft from an initial velocity and altitude to a final velocity and altitude in such a manner as to minimize the expenditure of time or fuel, or to maximize the parameters of average velocity or specific range (miles of range achieved per pound of fuel consumed), whichever is desired. It is the object of this note to present a method of graphically portraying the field or family of optimum paths as they appear in the Mach-altitude plane.

Dynamic Programing

A brief review of the dynamic programing technique under discussion is in order. Basically the assumption is made that any mission profile in a Mach-altitude plane can be approximated by a combination of incremental constant altitude accelerations or decelerations and incremental constant Mach number climbs or dives. The degree of accuracy established by this assumption is within the confidence level of the aerodynamic data usually available for the analysis. The particular study described here was performed using an IBM 709 high-speed digital computer.

The flight envelope of the aircraft is arbitrarily divided into increments of Mach number and altitude, the size of the increments depending upon such factors as required computational accuracy, available computer storage, correlation with achievable flight-measured accuracies, etc. Using the standard aerodynamic equations for aircraft performance, the values of time, fuel, and distance consumed in traversing the various increments of altitude and Mach are calculated. With the application of the technique of dynamic programing in its simplest form, the aircraft is constrained, in any one optimum analysis, to move in any two of the available four directions in the Mach-altitude plane.

The decrease in aircraft weight as fuel is consumed is included in the calculations. This procedure involves

the initial estimation of the fuel consumed during the trajectory, with a possible iteration required to achieve a precise quantitative calculation. However, it has been determined by the writer and others[1] that the general shape of the optimum profile is not drastically affected by moderate changes in initial aircraft weight. More directly a function of weight are the absolute values of time, distance, and fuel consumed in traversing these optimum paths. A normal lift load factor of 1.0 is assumed throughout the analysis. However, the effect of varying maneuver load factors can be evaluated with a modification to the 709 program. The condition of fixed engine power setting is also imposed for each particular analysis. These fixed power settings may vary from maximum afterburning power for a minimum time climb investigation to idle power for a maximum range descent case. The calculation procedure results in a family of optimum paths (optimizing the selected parameter such as minimum time, minimum fuel, etc.) emanating from all available points in the Mach-altitude spectrum and terminating at the selected end point or final condition.

Visual Display

As an adjunct to the original calculation procedure, the IBM 709 computer was programed to produce a visual printed output which portrays the families of optimum flight profiles as previously calculated. By observing the nature of the print character corresponding to the Mach-altitude condition under consideration, one can determine whether the aircraft is in a constant-Mach exchange of altitude or a constant altitude exchange of Mach. This graphic display is ideally suited to a rapid and clear presentation and evaluation of existing or future tactical flight profiles.

Fig. 1a indicates the nature of the printed display. This particular figure represents, for a typical interceptor aircraft, an array of paths which minimize the pounds of fuel consumed in reaching a cruise condition while the aircraft is operating at a constant power setting of military power along the entire transfer operation. Direction characters are presented at intervals of Mach and altitude corresponding to the quantitative calculation procedure. These increments may be varied at will. However, in the interests of clarity of presentation of both the calculated numerical array and the visual graphic output, the relative size of the increments should be chosen to give approximately equal increments of, say, time. In this manner, the paths will not appear skewed or biased in favor of one direction of movement. The character 1 indicates that, from the present Mach and altitude, the optimum path requires an acceleration at constant altitude to the next higher Mach. The character – indicates a constant Mach climb to the next higher altitude. Thus, by following the direction characters, the optimum path may be traced from *any* desired starting condition to the end condition for which the particular array was generated.

(*Continued on page 46*)

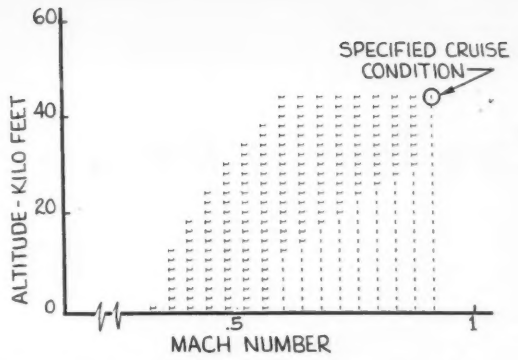

Fig. 1a. Array of minimum-fuel paths to specified cruise condition, operating with full military power.

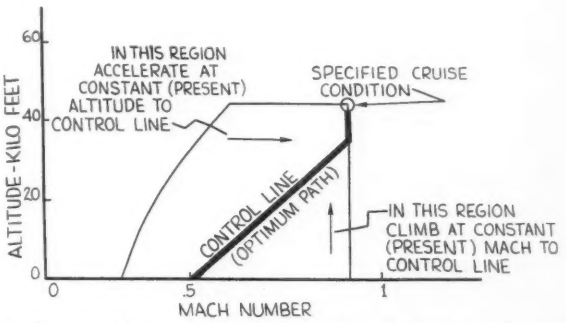

Fig. 1b. Simplified flight control logic for minimum-fuel path to cruise condition.

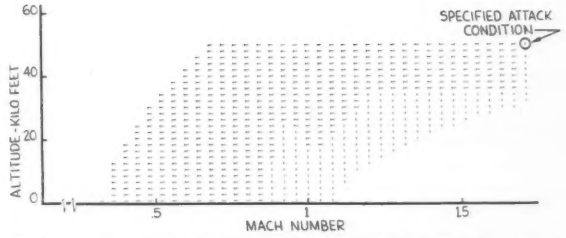

Fig. 2a. Array of minimum-time paths to specified attack condition, operating with maximum afterburning power.

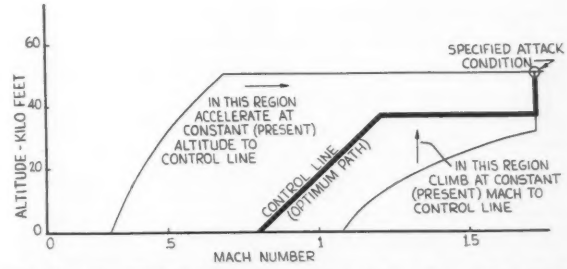

Fig. 2b. Simplified flight control logic for minimum-time path to attack condition.

Zero Gravity Mercury Condensing Research

Mercury condenser apparatus test problems during zero g were explored by setting the liquid-vapor interface in view near the right end of the glass condenser, which permitted observation of the condensing and the liquid-vapor interface primarily for qualitative fluid mechanics phenomena. The conclusions from these tests are applicable to three areas of space power system technology—feasibility demonstration, ground test validation, and problem identification.

John G. Reitz, *Thompson Ramo Wooldridge Inc.*

A NUMBER OF independent analyses have indicated that Rankine cycle power systems utilizing liquid metal working fluids provide a very promising high-level power source for space vehicle applications (other than propulsion). Such power systems, which have heretofore enjoyed the presence of gravity forces in ground applications for proper operation, could encounter new problems in a zero gravity environment. Problem areas of particular concern are the liquid and liquid-vapor regions of a Rankine cycle power system.

The first series of mercury condensing tests for zero gravity periods of 11 to 15 sec. have been completed by the Thompson Ramo Wooldridge New Devices Laboratories. These tests were conducted aboard the WADC C131B Air Force airplane in which a Keplerian trajectory was utilized to obtain a zero gravity force field.

Purpose

This first series of zero *g* tests was part of a condenser research program ultimately to design trouble-free liquid metal space condensers. The purpose of the tests was to explore mercury condenser apparatus test problems during zero *g*. These mercury condensing problems were explored by setting the liquid-vapor interface in view near the right end of the glass condenser, which permitted observation of the condensing and the liquid-vapor interface primarily for qualitative fluid mechanics phenomena.

Results

The results of the zero *g* tests can contribute to space vehicle power system technology in three ways—feasibility demonstration, problem identification, and ground test validation. These results may be outlined as follows:

Mr. Reitz received a B.A. degree (1949) from Wooster College, an M.A. (1950) from Western Reserve University, and a B.S. (1956) in mechanical engineering from Case Institute of Technology, where he is now taking courses toward an M.S. in mechanical engineering. He joined TRW in 1956 as a Product Engineer, assuming technical responsibility for preproduction and production of various aircraft booster pumps, turbine-driven water injection pumps, and fuel valves, and assisted in the development of the Bomarc shelter roof actuator. Most recently he has served on zero gravity condenser experiments in the New Devices Lab. He has designed various heat-transfer devices and has developed an engineering scheme for determining heat transfer and temperature maps of complex-shaped items. He is presently engaged as Lead Engineer in the orbital force field boiling and condensing experiments.

Feasibility Demonstration

(1) Boiling and condensing of mercury in zero gravity were performed.

(2) A definite demarcation between the condenser and subcooler regions was maintained.

Problem Identification

(3) The liquid mercury rapidly moved left and filled the condenser tube as zero gravity was approached because of the expansion of compressed gases trapped in the pressure gage as the gravity head was removed.

(4) The degree of success in evacuating noncondensable gases was shown to have an effect on the condensing regions and interface in zero *g* as well as on the ground.

(a) The build-up of noncondensable gases was sometimes great enough to reduce the effective condensing area substantially.

(b) The condensate droplet size was directly related to the amount of noncondensable gas in the condenser in front of the liquid. This combination of noncondensable gas and droplet enlargement caused

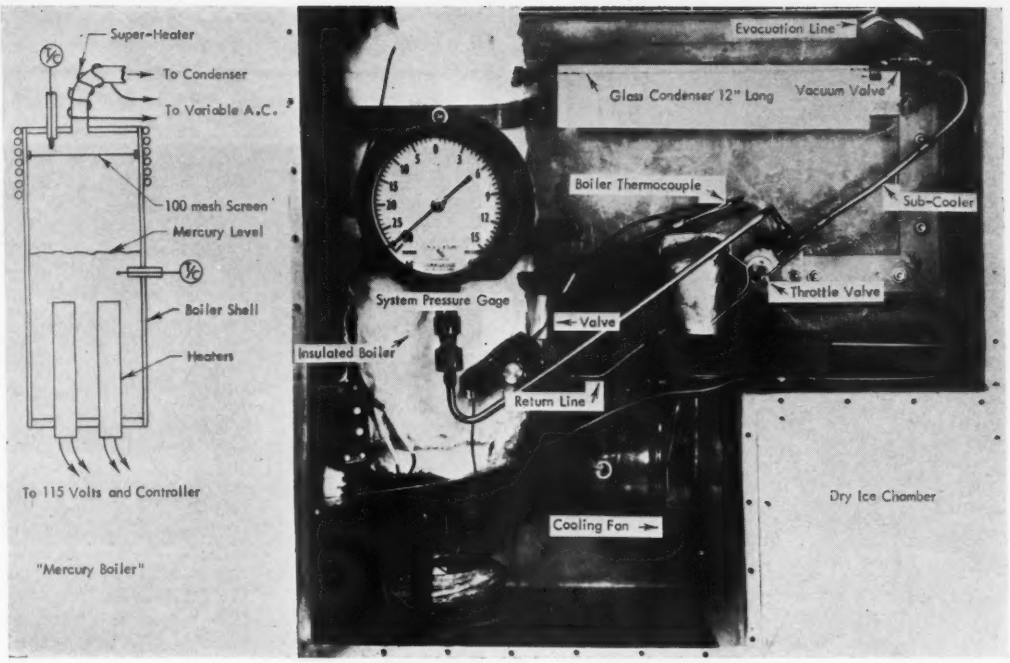

Fig. 1.

noncondensable gases to get trapped in the condensate feed line. In a power system, this situation could cause the pump to cavitate.

(c) During one *g*, when noncondensable gases were present, the interface slope was less vertical than when noncondensable gases were absent.

(5) When gravity forces were removed, the condensate droplets were no longer compressed to the bottom of the tube and the larger drops tended to fill the entire cross section of the tube.

(6) The interface slope was a function of *g* forces and the amount of noncondensables present. Under zero g, the interface was vertical; under one g, it was slanted with the top to the right; and under higher *g* forces (1.8 to 2.5g), the subcooled liquid was compressed so that the lower part of the interface was squeezed out.

(7) The aqua-colored glow (probably caused by thermal excitation of the mercury atoms) was inversely related to the pressure and directly related to the temperature. Under steady-state conditions, it occurred in the full length of the glass tube when the return valve to the boiler was open, and it occurred only at the boiler outlet where the condensate droplets were just forming when the liquid was filled up to the glass condenser. However, a glow throughout the condenser was inducible by using various means to increase the vacuum.

Correlation to Ground Testing

(8) It was demonstrated that droplet size was inversely related to condensing rate and velocity in zero g as well as one g.

(9) In regard to apparatus shakedown problems, all elements and the loop worked satisfactorily except for the trapped gases in the bourdon tube. This problem was corrected by the installation of a valve in the line to the pressure gage.

Test Apparatus

A photograph of the mercury loop and a diagram of the boiler appear in Fig. 1. From the boiler diagram, it can be seen that the test apparatus consisted of a stainless-steel, electrically heated mercury boiler, which generated mercury vapor that passed through a screen near the top of the boiler and into the condenser. The screen was to prevent the liquid mercury from wander-

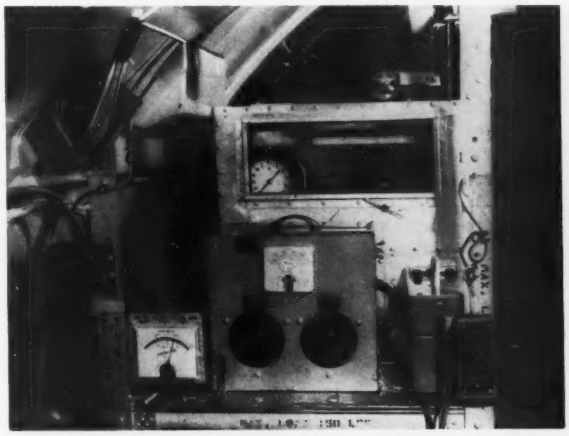

Fig. 2.

Fig. 3. Liquid mercury moving left as zero *g* is approached.

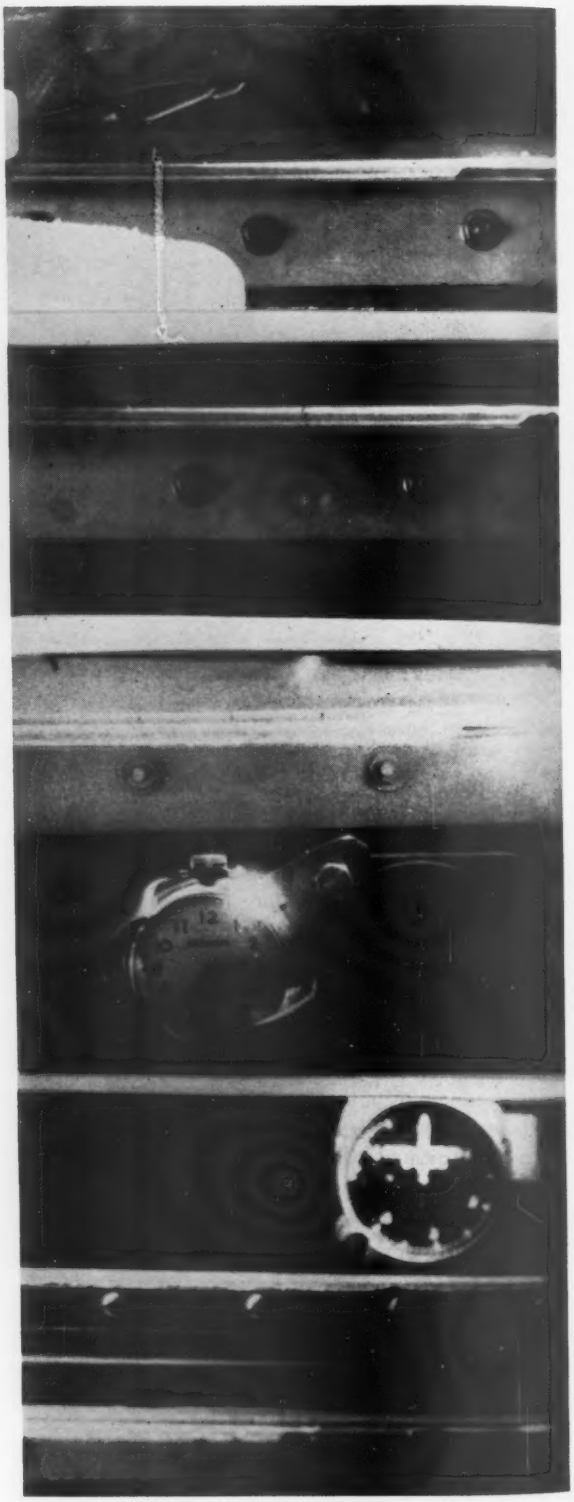

Fig. 4. Effect of noncondensable gas on drop size. (*Top to bottom:* Ground test, noncondensable gas; ground test, no noncondensables; flight 2, run 2; and flight 1.)

ing up into the condenser during zero g. At the left of the picture, the insulation over the boiler can be seen; at the top is the condenser which was made of glass permitting observation of fluid mechanics phenomena. To complete the loop, there was a gravity return line back to the base of the boiler with a shutoff or throttle valve which was generally kept closed except to permit the mercury condensate to run back to the boiler when necessary. The density ratio between the mercury vapor and liquid mercury is so low (approximately 23,000) that vapor velocities of about 100 ft./sec. can be obtained with a condensate build-up of about 1/2 in. length of the condenser tube in the time interval of a zero g maneuver. By dumping the mercury from the condenser between zero g dives, quasi-steady-state conditions were thereby obtained.

System pressure and boiler temperature were controlled by automatic temperature control of the boiler. The superheat was manually controlled by means of a Variac. Instrumentation consisted of thermocouples to the boiler, superheater, and subcooler regions. A compound pressure gage was connected to the subcooler region. The condenser was cooled by air blown from an integral centrifugal fan. The installation of the test apparatus can be seen in Fig. 2.

Test Conditions

The differences between the test conditions in the first and second flights were as follows:

(1) In the first flight, zero g intervals of about 6 sec. were obtained. In the second flight, the addition of an oil expulsion system to the aircraft propeller hydraulic system resulted in the attainment of 11- to 15-sec. zero g intervals.

(2) In the second tests, the noncondensables were reduced sufficiently to distinguish between condenser performance with and without their presence.

(3) For the second flight, a shutoff valve was installed in the line to the pressure gage to isolate the effect of the noncondensables trapped in the pressure gage.

(4) In the first flight, no test conditions were intentionally varied. In the second flight, conditions were varied as shown in Table 1.

Boiling temperatures of about 500°F. were maintained throughout all tests. Mercury vapor temperatures slightly above 500°F. were maintained in all the tests except the first flight where the superheat was gradually increased from 500° to 700°F. from the first to the last flight.

Table 1.

Zero g Interval	Valve to Pressure Gage	Condenser Cooling Fan
1	Open	On
2	Closed	On
3	Closed	On
4	Open	On
5	Open	Off
6	Closed	Off
7	Closed	On
8	Open	On
9	Closed	On
10	Closed	On
11	Closed	On
12	Closed	On

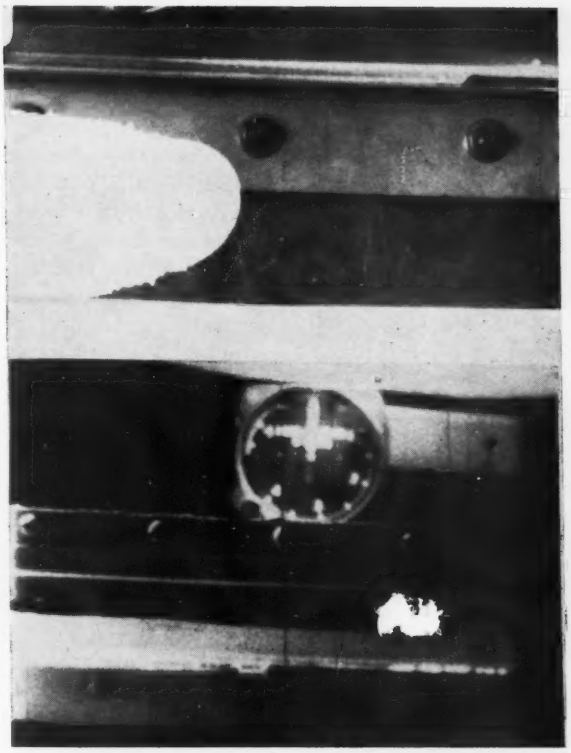

Fig. 5. Effect of gravity on droplet orientation. (*Top to bottom:* Ground test and flight 1.)

Interpretation of Results

To have a better idea of what occurred in the tests, the movie film of the tests should be seen. However, significant frames of the films are presented here which, with the inclusion of the g meter and clock, give some indication of what occurred.

(1) The condensate droplets can be seen in Figs. 3–6. That boiling (and also condensing) occurred during zero g can be calculated from the build-up of liquid condensate (3/4 in. in 10 sec.). This condensation rate (0.065 lb./min.) corresponds to the rate obtained in ground tests.

The following figures show that the amount of condensate was greater than the amount which could be obtained from the mercury vapor generated prior to zero g alone. Calculating the weight from the corresponding specific volume of mercury at 500°F., $v = 27$ ft.^{3}/lb., and the vapor volume in the boiler (which was 28 in.^{3}) gives a weight of 0.00055 lb., which is much less than the weight of 0.01 lb. actually condensed in that time interval.

(2) A significant result was that demarcation between the subcooler and condenser was maintained during zero g. Many of the films and pictures show this.

(3) The leftward movement and filling of the condenser as zero g was approached is readily explicable

now, although its occurrence was not anticipated in the first flight. The phenomena can be explained thus: Noncondensables were trapped in the pressure gage when the system was first heated up and condensation started, and the head of mercury compressed the gas with normal gravity forces on it. When the gravity forces were removed, the gases then expanded to a new, larger volume corresponding to the pressure with gravity minus the liquid pressure head, and thereby forced the liquid mercury up into the condenser tube. This was verified by installing a valve in the line to the pressure gage for the second test. The valve could then be closed off after the liquid mercury built up to the glass condenser tube and there was only liquid in the line below the condenser. Results of the second test showed that, when the valve was open, the liquid filled the condenser tube at zero g. When the valve was closed, the interface maintained its position.

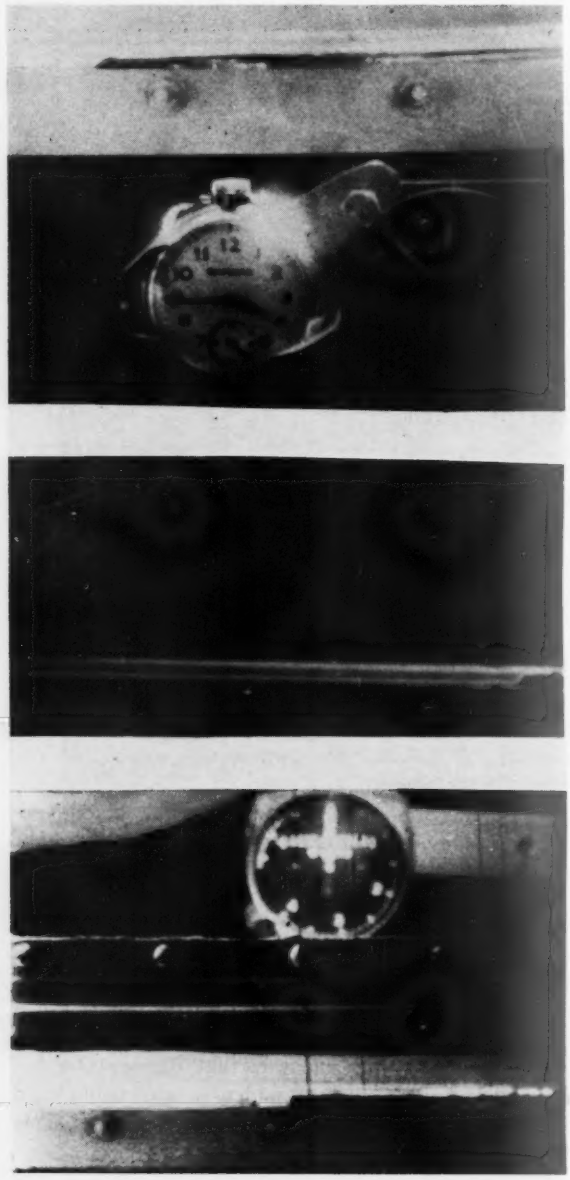

Fig. 6. Effect of gravity on interface slope.
(Top to bottom: High g, run 2; ground test; and zero g.)

Compare Fig. 3 where the valve was open with nearly all the other figures when the valve was closed. By observing the g meter and the liquid locations in Fig. 3, we see that they correspond. As the gravity forces on the liquid mercury head were decreased, the liquid moved left.

(4)(a) The great difficulty encountered in eliminating noncondensable gases brought some serious problems to light. The first time the loop was tested, it was demonstrated rather clearly how the presence of noncondensables can reduce a condenser's effectiveness. There was no mercury condensing to be seen in the glass tube in spite of the fact that temperatures were raised well above what is required for the condensation of mercury. The reason the test loop did not appear to function was that the condenser was filled with noncondensable gases. The presence of such gases can be seen in Fig. 4 (bottom picture), which is a picture taken in the latter part of the first flight.

(b) The presence of even small amounts of noncondensables can cause problems. The noncondensables were present because a vacuum pump, which took the pressure down to 100 microns, was used to evacuate the gases, and, when a mass of gas at this pressure and a volume of half of the boiler was carried up into the condenser in front of the liquid condensate, a fair volume of the tube was still filled with noncondensables with a loop pressure of 2 psia. This problem was fairly well solved by installing an evacuation valve near the condenser. When these noncondensables were present, they showed themselves capable of causing trouble by being entrapped and carried through the subcooler to the pump, and in a power system they would cause cavitation of the pump. The entrapment occurs because, with the noncondensable gas in front of the subcooler, the condensate drops grow large enough to fill the tube cross section. This problem will be even more difficult with the condenser tube diameters anticipated. This tube was 0.196 in. I.D., and ground stability tests showed that a maximum of 0.15 in. I.D. tube is necessary at one g and room temperature to assure interfacial stability. Therefore, smaller drops will be large enough to fill the whole diameter and entrap the noncondensable gas. See Fig. 4 for a comparison of drop size for different degrees of gas evacuation, both in ground tests and in the air (zero g).

(c) Following is an explanation for a decrease in interface slope with increased noncondensable gases. When the gases build up in front of the interface, the mercury and droplets are prevented from impinging on the interface, which means that the momentum forces tending to hold the interface in a vertical position are removed. Therefore, the interface becomes less vertical. Surface tension is the only force which remains to prevent the gravity forces from causing the liquid surface or interface to become completely level.

(5) The fact that smaller droplets will fill the tube cross section during zero g than with normal g forces indicates further that noncondensables must be eliminated in a space power system. Notice the difference in shape between the drops in the pictures in the top half and those in the bottom half of Fig. 5.

(6) The effect of various g forces on the interface shape brings attention to fluid mechanics problems which might arise when some future test system or power system encounters high gravity force fields either in pulling into zero g in an airplane flight pattern, such as this, or in a rather highly accelerated rocket. For example, if condenser tubes in a system were oriented horizontally, g forces could compress the liquid enough that it would fill the bottom part of the whole condenser tube length and the condenser and subcooler regions would not be maintained in the locations intended and, therefore, not perform as required. In general, it can be seen that liquids in a fluid system, which undergoes high g forces, could be disoriented sufficiently when zero g is reached to cause the liquid and vapor to go to locations not intended either permanently or at least long enough to abort a test or a system performance (see Fig. 6).

Since the interface behavior is of particular importance, this information on the relationship of interface orientation and g forces could contribute to other phases of condenser research analysis.

(7) By turning off the condenser cooling fan and greatly reducing the tube heat-transfer coefficient, the condensing rate was reduced which in turn reduced the mass flow and the vapor velocity; consequently, the droplets were larger.

Fig. 7 shows a comparison of the droplet sizes with the cooling fan on and with the fan off for zero g conditions. The same phenomenon has been observed numerous times in ground tests.

This demonstrates the general agreement between the condensing process during zero g and during one g, and it demonstrates that there is nothing to invalidate the TRW ground experimental and analytical research program for zero g condensers. The quantitative results of the ground research program can, therefore, be used in conjunction with the zero g condenser test results for designing workable space condensers.

Conclusions

The conclusions from these tests are applicable to three areas of space system power technology—feasibility demonstration, problem identification, and ground test validation.

Feasibility Demonstration

(1) Boiling and condensing of mercury in a gravity-free environment can be performed.

(2) Demarcation between the condensing and subcooling regions can be maintained in zero gravity.

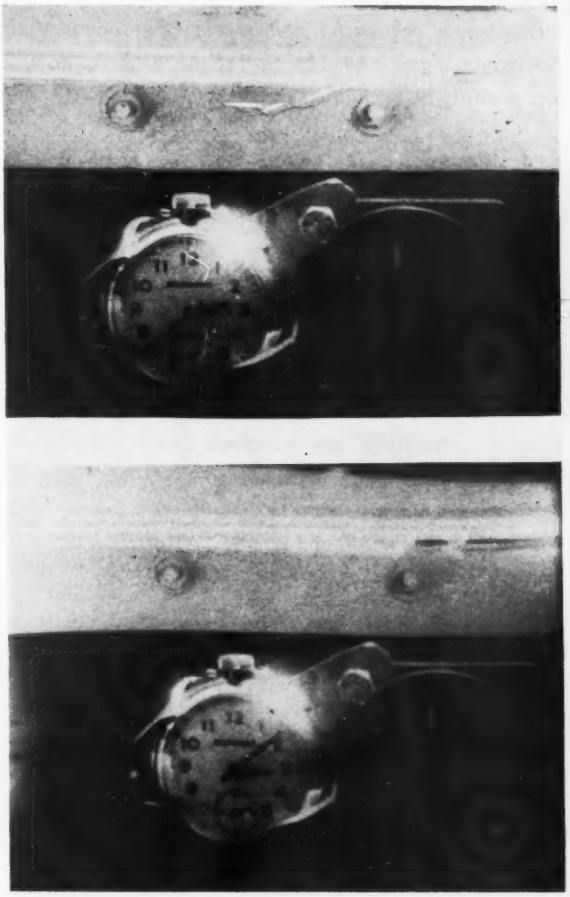

Fig. 7. Effect of condensing rate on droplet size. (*Top to bottom:* Flight 2, run 2, and flight 2, run 6.)

Ground Test Validation

(3) There was no evidence which would invalidate analyses of mercury condensing for zero g based on tests conducted in a one g environment. The following information, rather than contradicting, adds to the fund of technical information required to design zero g condensers.

Problem Identificatcn

(4) Space power systems should be designed to avoid the possibility of noncondensable gases being trapped somewhere in the loop, causing the condenser to be filled with liquid mercury when zero g is reached and thus rendering the condenser ineffective.

In general, the various gravity forces, including high g forces, which a test apparatus or space power system will see must be considered in order to assure that liquids or vapors do not go to a location which will render the system less efficient, less reliable, or completely ineffective.

(5) Ground and zero g tests indicated that noncondensables must be removed from the system since large amounts can greatly reduce a condenser's ef-

(*Continued on page 46*)

"This type of approach will help orient the designs of aircraft regarding aerodynamic and control configurations, artificial damping, and stability augmentation requirements."

A New Modified Acceptance Criterion for Lateral-Directional Flying Qualities

Robert M. Crone, MIAS, and Ralph C. A'Harrah, MIAS
North American Aviation, Inc.

THE PILOT of today's supersonic aircraft is performing maneuvers at altitudes and Mach numbers which were unobtainable when most of the present flying qualities specifications were written. The major flying qualities area affected by this growth of the flight envelope is the lateral-directional flying qualities which suffer from a disconcerting increase in Dutch roll coupling and lateral control cross coupling.

The purpose of this pilot evaluation study, conducted on a stationary simulator, was to investigate the validity of existing lateral-directional criteria and to study the need for additional criteria in the high Mach number, high-altitude flight region; it was based on the premise that the pilot's tasks preclude continuous monitoring of the aircraft's attitude, thus excluding VFR take-off and landing considerations.

The parameter variations were sufficiently broad to include the Dutch roll and lateral control characteristics for a majority of contemporary and near-future aircraft.

Simulator Description

The stationary flight simulator used in this investigation consisted of a cockpit mock-up coupled with an analog computer. The cockpit mock-up included a fixed seat; a functional control system with fixed linear force characteristics typical of contemporary aircraft; and a visual display of an all-attitude indicator, ball and bank indicator, normal accelerometer,

A revised and condensed version of the authors' IAS 28th Annual Meeting paper, presented under the title, "Development of Lateral-Directional Flying-Qualities Criteria for Supersonic Vehicles, Based on a Stationary Flight-Simulator Study" (IAS Paper 60-18).

Symbols

b	=	wing span, ft.
C_l	=	rolling moment coefficient
C_n	=	yawing moment coefficient
C_Y	=	side force coefficient
$C_{1/2}$	=	number of cycles for oscillation to damp to half amplitude, cycles
g	=	unit of gravitational acceleration, 32.2 ft./sec.^{2}
I_X	=	yaw inertia, slug ft.^{2}
I_Z	=	roll inertia, slug ft.^{2}
L	=	$57.3\ qSbC_l/I_X$, deg./sec.^{2}
m	=	mass, slugs
N	=	$57.3\ qSbC_n/I_Z$, deg./sec.^{2}
P	=	period of oscillation, sec.
p	=	roll rate, deg./sec.
$\lvert p \rvert$	=	amplitude of roll rate oscillation, deg./sec.
$\lvert p \rvert_1$	=	amplitude of roll oscillation at first overshoot, deg./sec.
p_{ss}	=	steady-state roll rate, deg./sec.
$\lvert p_{ss} \rvert$	=	absolute value of steady-state roll rate, deg./sec.
q	=	dynamic pressure, lbs./ft.^{2}
r	=	yaw rate, deg./sec.
S	=	wing area, ft.^{2}
s	=	Laplace transform operator
T	=	time of first roll rate overshoot, sec.
$T_{1/2}$	=	time for oscillation to damp to half amplitude, sec.
t	=	time, sec.
V	=	resultant velocity, ft./sec.
$\lvert v_E \rvert$	=	amplitude of lateral equivalent velocity oscillation, ft./sec.
Y	=	$57.3\ qSC_Y/Vm$, deg./sec.^{2}
β	=	sideslip angle, deg.
$\lvert \beta \rvert$	=	amplitude of slideslip oscillation, deg.
β_0	=	zero frequency sideslip displacement, deg.
δ	=	lateral control deflection, deg.
ζ	=	damping ratio of oscillatory mode
Φ	=	phase angle lag of p to β, rad.
ϕ	=	bank angle, deg.
$\lvert \phi \rvert$	=	amplitude of bank angle oscillation, deg.
ω	=	damped frequency, rad./sec.
ω_n	=	natural frequency, rad./sec.

Mr. Crone received his B.S. degree in engineering with aero option in 1943 from the Iowa State College. During the following 4-year period he was employed as an aerodynamics engineer at Douglas Aircraft, and also served in the U.S. Navy as Navigator and as Professor of Naval Science and Tactics at Princeton University. He joined North American Aviation in 1947, and has been associated continuously since that time with Aerodynamic Design and Development. He is currently Chief of the Aero-Thermo Sciences at North American, Columbus Division.

Mr. A'Harrah received his B.S. degree in aeronautical engineering from the Pennsylvania State University in 1955. Since graduation he has worked at North American, Columbus Division, with the exception of a 1-year leave of absence to do graduate work in aeronautical engineering and teach at the Ohio State University. He has been primarily concerned with the dynamic stability and control characteristics of supersonic and V/STOL aircraft and missiles.

Machmeter, and altimeter. Black drapes were used to shroud the cockpit during the test in order to eliminate peripheral distractions to the pilot.

The analog computer mechanization included the six degree of freedom airplane equations of motion and the control system transfer functions which had time constants typical of those for irreversible controls.

Pilot Background

The eleven pilots participating in this evaluation had either engineering degrees or engineering backgrounds. Six pilots had extensive flight-test experience (average flight time 5,132 hours, average flight-test time 2,000 hours) and the remaining five had service backgrounds (average flight time 1,480 hours).

Considering the number and cross section of pilots participating, the average opinion of the group should be relatively free of the effects of singular idiosyncrasies and representative of the opinion of pilots involved in flying military aircraft.

Test Procedure

Eleven pilots flew the simulator for a total of 28 evaluation periods. From 14 to 23 configurations were evaluated during each period. The numerous configurations included various levels of directional stability, directional damping, dihedral effect, lateral control yawing moment, and lateral damping.

The four types of maneuvers performed during the evaluation of each stability configuration were (1) entry to and exit from a standard rate turn (bank angle of 30°), (2) abrupt directional control kicks and release, without pilot correction, (3) one g 60°-60° and 90°-90° rolls using full lateral control, and (4) evasive action which consisted of abrupt rolling while pulling a normal load factor of 3–4g.

After an indoctrination and learning period on the simulator, the pilots performed the above maneuvers as many times as desired. They were also allowed to perform any other maneuver(s) which they felt would aid in their evaluation. Following these investigations, four characteristics were rated—ability to coordinate maneuvers, directional oscillatory characteristics, 1g rolling characteristics, and 3–4g rolling characteristics.

The ratings available to the pilots for grading these items were *excellent*, *satisfactory*, *acceptable*, *emergency conditions only*, and *unflyable*.

Method of Data Assimilation and Analysis

Data were obtained from the pilot evaluation sheets, from voluntary comments recorded on tape, and from twelve channels of analog recording of pilot control inputs, airplane accelerations, and rates.

The major and significant results from this study were obtained from the analysis of pilot evaluation data. These data were reduced by taking the arithmetic mean of all the pilot ratings for a given configuration evaluated during a specified maneuver. Frequency curves for three typical configurations are shown in Fig. 1. It is noted that for all practical purposes the median and the average are the same value for the individual configuration being evaluated. Also shown are the standard deviation values which are an index of the dispersion of the rating about the average rating. The average deviation for the complete test was 0.82 of a rating point. The average standard deviation for the pilots evaluating the same configuration twice during a single evaluation period was 0.31 of a rating point, showing an acceptable level of repeatability.

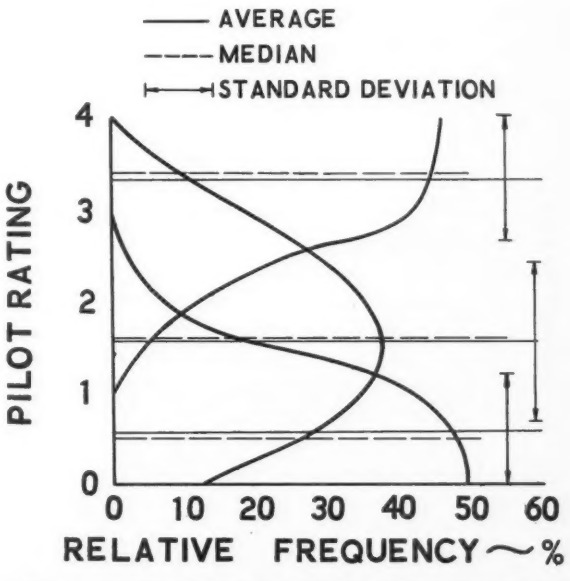

Fig. 1. Frequency distribution of pilot rating for three representative configurations.

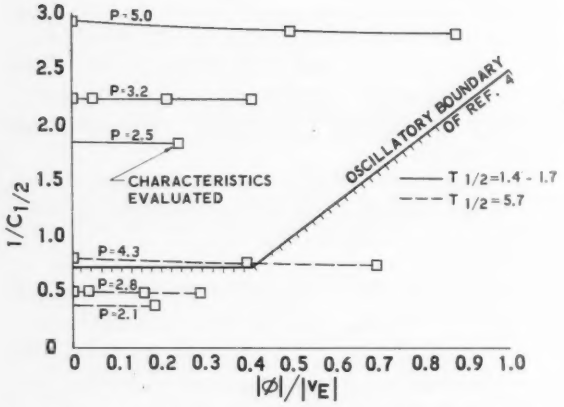

Fig. 2. Range of lateral directional characteristics investigated.

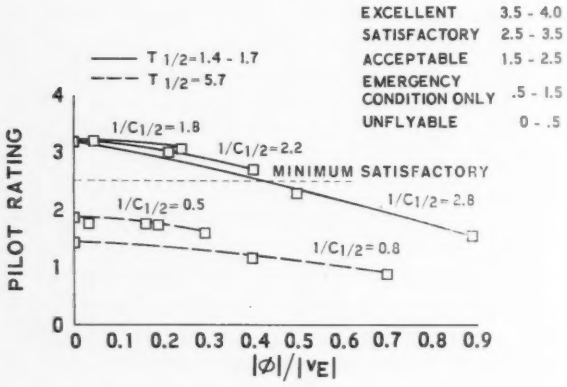

Fig. 3. Variation of pilot rating with $|\phi|/|v_E|$.

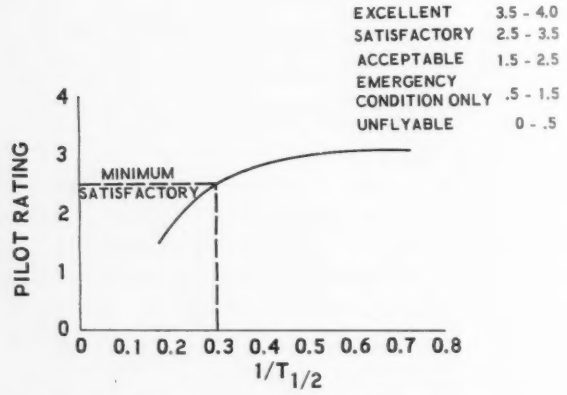

Fig. 4. Variation of pilot rating with $1/T_{1/2}$, $0 < |\phi|/|v_E| < 0.4$.

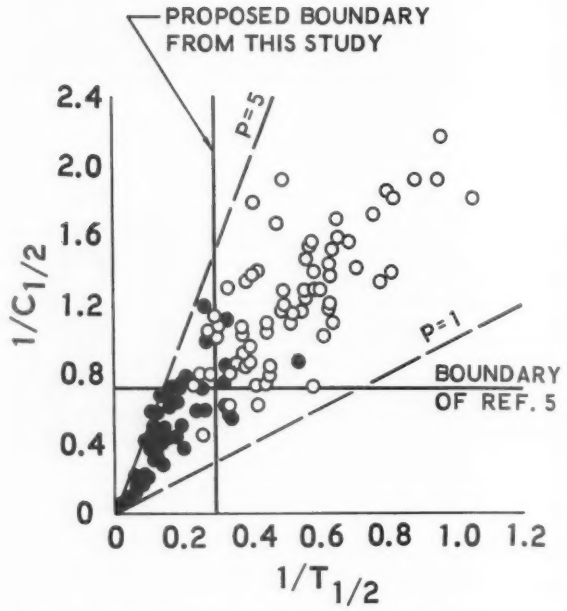

Fig. 5. Pilot evaluation data from flight evaluation of lateral-directional damping, $0 < |\phi|/|v_E| < 0.4$.

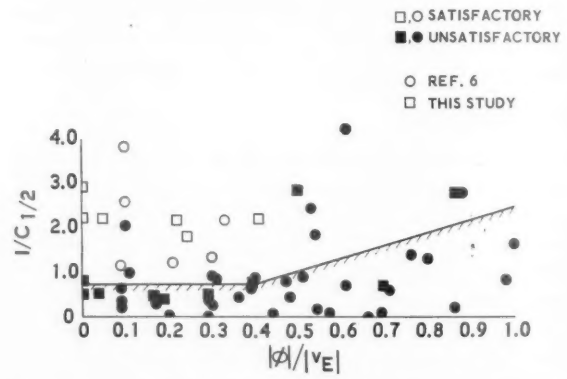

Fig. 6. Comparison of pilot opinion with presently specified lateral-directional oscillatory requirement.

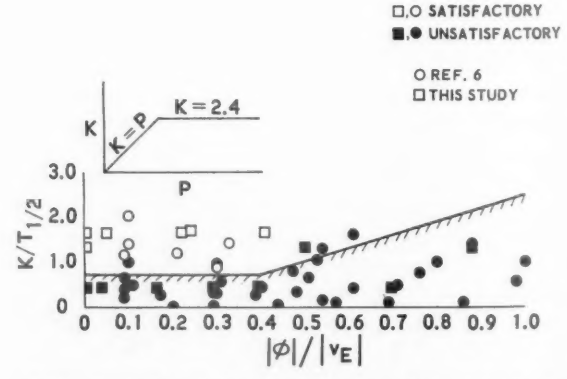

Fig. 7. Comparison of pilot opinion with proposed lateral-directional oscillatory requirement.

Tape-recorded comments were mainly an amplification of the pilots' opinion of the various configurations. These comments, coupled with the analog recording of the pilots' control inputs and airplane responses, were used to give some insight into the more obscure factors influencing the pilot rating and were, therefore, useful in defining parameters which would best correlate the pilot rating with the various lateral-directional characteristics.

The values of time to damp to half amplitude, frequency, and the ratio of bank angle to sideslip angle were measured from the time histories and checked against the values obtained from digital computer solutions of the lateral-directional quartic in order to assure correctness and consistency of results.

Dutch Roll Coupling Characteristics

The ranges of lateral-directional oscillatory characteristics evaluated in this study are shown in Fig. 2, along with the presently specified Dutch roll acceptance boundary.[4] Two broad damping regimes were investigated—(1) that which is typical of the unaugmented aircraft, as indicated by the dashed curves, and (2) that which is typical of the augmented aircraft.

The lateral-directional oscillatory characteristics were evaluated by the pilots during oscillations induced by abrupt directional control inputs. The evaluation was conducted on the premise that the required pilot tasks were of such complexity as to prohibit continual monitoring of the aircraft's attitude. Therefore, the pilots were instructed to evaluate the oscillatory characteristics prior to making any corrective control inputs.

The variations of pilot rating with $|\phi|/|v_E|$ are shown in Fig. 3 for various values of the cyclic damping parameter $1/C_{1/2}$. Note that some of the characteristics rated below the minimum satisfactory rating in this study (pilot rating = 2.5) are well within the presently specified satisfactory boundary[4]—e.g., $|\phi|/|v_E| = 0.5$ and 0.88 on the $1/C_{1/2} = 2.8$ curve. Also note that for a constant level of Dutch roll coupling, the pilots are influenced by the time to damp rather than by the number of cycles to damp, for the range of stability characteristics investigated in this study. This is witnessed by noting that the pilot rating improves as the cyclic damping parameter is increased by a corresponding change in $T_{1/2}$—i e., going from dashed to solid curves. However, when the cyclic damping parameter is increased but $T_{1/2}$ remains constant as in the dashed or solid region, the pilots are either adversely affected or insensitive to the variation.

In other words, the pilots feel an improvement in the flying qualities when $1/C_{1/2}$ is increased by increasing the directional damping. But the pilots feel either a deterioration, or relatively no change, in the flying qualities when $1/C_{1/2}$ is increased by reducing directional stability. Therefore, for the range of lateral-directional stability characteristics of this study, the acceptance of the lateral-directional damping is primarily a function of the time to damp parameter.

In order to establish the minimum level of directional damping which the pilots consider to be satisfactory, a cross plot was made of pilot rating vs. the time to damp parameter $1/T_{1/2}$ for a constant $|\phi|/|v_E|$ value of 0.2, considered to represent the average variation for the $|\phi|/|v_E|$ range from 0 to 0.4. This cross plot, Fig. 4, indicates the minimum level of directional damping the pilots consider satisfactory, which is $1/T_{1/2} = 0.3$.

A comparison of the results from this simulator study with a similar investigation[5] utilizing a variable stability aircraft is shown in Fig. 5. The $1/T_{1/2} = 0.3$ boundary established in this study is superimposed on the pilot evaluation data and the resulting boundary at $1/C_{1/2} = 0.72$ of the referenced study. Individually, both boundaries appear equally effective for separating the satisfactory characteristics from the unsatisfactory. However, a combination of the two boundaries improves the effectiveness considerably. That is, a better acceptance boundary is obtained by using the $1/C_{1/2}$ boundary for the short-period oscillations and the $1/T_{1/2}$ boundary for the longer-period oscillations. The logical change-over point is the period at which the two boundaries intersect, which is 2.4 sec.

Thus it has been shown that for a moderate range of Dutch roll coupling ($0 < |\phi|/|v_E| < 0.4$), the present $1/C_{1/2}$ boundary should be used for periods of oscillation shorter than 2.4 sec. but, for the longer periods, the $1/T_{1/2}$ is required.

In order to show that this approach is valid for the full range of $|\phi|/|v_E|$ values, pilot opinion data from this study and from a flight evaluation study[6] conducted by NASA will first be compared with the presently specified boundary and then with the proposed boundary.

Fig. 6 shows the pilot evaluation data and present oscillatory boundary on the conventional $1/C_{1/2}$ vs. $|\phi|/|v_E|$ plot. Note the number of points which were considered unsatisfactory by the pilots but which are well within the specified satisfactory boundary. Neglecting the borderline cases, there are seven such points of gross disagreement.

Fig. 7 represents the same pilot evaluation data on a $K/T_{1/2}$ vs. $|\phi|/|v_E|$ plot, where the $F/T_{1/2}$ parameter allows simultaneous consideration of both the $1/C_{1/2}$ and $1/T_{1/2}$ requirements. That is, $K/T_{1/2}$ is equal to $1/C_{1/2}$ for periods less than 2.4 sec. with the damping boundary at 0.72 for moderate $|\phi|/|v_E|$ values. At periods longer than 2.4 sec., the parameter $K/T_{1/2}$ is equivalent to $1/T_{1/2}$ with a boundary at 0.3 for the moderate $|\phi|/|v_E|$ values.

The improved agreement between the pilots' opinions and the proposed boundary is indicated by noting that seven points of gross disagreement shown in Fig. 6 are now compatible with the boundary as defined here. Also, it is noteworthy that none of the characteristics considered satisfactory by the pilots fall outside the

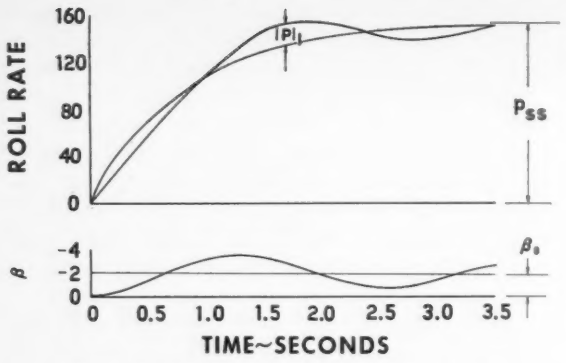

Fig. 8. Typical response to step input of lateral control.

boundary, which indicates that the proposed boundary is not overly conservative.

Therefore, it is concluded that the lateral-directional damping boundary expressed in terms of $K/T_{1/2}$ is more representative of pilot opinion than the presently specified boundary expressed solely in terms of $1/C_{1/2}$.

Lateral-Directional Maneuvering Characteristics

Experience with contemporary high-speed aircraft has shown that satisfying the Dutch roll acceptance criterion discussed in the previous section and the specified roll response requirements[4] does not ensure satisfactory lateral maneuvering characteristics. This was further verified from the results of this study. Therefore, an attempt was made to establish an additional criterion relating basic aircraft characteristics to pilot acceptance of the lateral maneuvering characteristics.

These characteristics were evaluated by the pilots while flying three maneuvers—entrance and exit to a standard rate turn, full lateral control, 90-90 deg. rolls at 1*g*, and 3–4*g* rolling pull-outs.

During the averaging of the pilot rating from the standard rate turns and the 1*g* rolls, it became apparent that, for the range of lateral-directional oscillatory characteristics and lateral control characteristics considered in this study, the pilots were assessing the coordination characteristics the same as the 1*g* roll characteristics. The evaluation data for these two maneuvers were therefore combined to give a single correlation of pilot rating of the 1*g* lateral handling qualities.

The lateral handling qualities characteristics have long been recognized to be dependent on the lateral control characteristics, the roll damping, and the lateral directional oscillatory characteristics. Therefore, in order to correlate pilot opinion effectively with the lateral handling qualities characteristics, it is necessary to determine a parameter which is properly dependent on these characteristics.

Such a parameter was found to be the ratio of the amplitude of the oscillatory roll rate at the first overshoot to the steady-state roll rate.

To describe this parameter better, a typical roll rate and sideslip time history for an abrupt roll control input is shown in Fig. 8. The sideslip oscillation, which is induced by the lateral control yawing moment, will feed back through the Dutch roll coupling and cause a roll oscillation, as indicated by the roll time history. The correlation parameter is simply the ratio of the amplitude of the roll oscillation at the first overshoot, designated as $|p|_1$, divided by the steady-state roll rate p_{ss}.

This ratio is adequately represented by the following equation:

$$\frac{|p|_1}{p_{ss}} = \frac{|p|}{|\beta|}\left[\frac{\beta_0}{\delta}\, e^{-\zeta\omega_n T}\right]\frac{\delta}{p_{ss}}$$

where

$$\frac{|p|}{|\beta|} = \frac{|\phi|}{|\beta|}\,\omega_n \approx \frac{L_\beta}{(\omega_n^2 + L_p^2 + 2\zeta\omega_n L_p)^{1/2}}$$

$$\frac{\beta_0}{\delta} \approx -\frac{N_\delta}{N_\beta}$$

$$-\zeta\omega_n T = (0.347/C_{1/2})(1 + \Phi/\pi)$$

$$\Phi \approx \tan^{-1}[\omega/(\zeta\omega_n L_p)]$$

$$\frac{p_{ss}}{\delta} \approx \frac{L_\delta - L_\beta\,(N_\delta/N_\beta)}{-L_p}$$

The first term on the right-hand side of the equation is simply the ratio of the amplitudes of the oscillatory roll rate to sideslip angle of the Dutch roll mode. The bracketed quantity represents the amplitude of the sideslip angle per unit of lateral control input at the time of the first roll rate overshoot. The last term of the expression is the reciprocal of the uncoordinated steady-state roll rate per unit of lateral control input. It is significant that, instead of using the pure rolling effectiveness L_δ, the equivalent rolling effectiveness $L_\delta - L_\beta(N_\delta/N_\beta)$ in the uncoordinated roll is used. This approach permits correlation of both adverse and favorable lateral control yaw conditions in an asymmetric manner.

The variation of pilot rating with the correlation parameter $|p|_1/p_{ss}$ for both the 1*g* and 3–4*g* evalua-

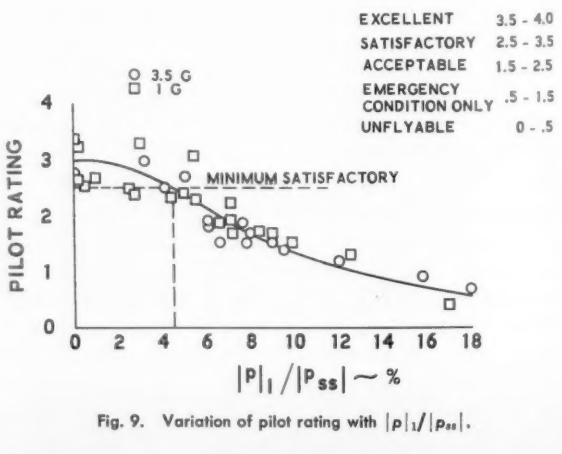
EXCELLENT 3.5 - 4.0
SATISFACTORY 2.5 - 3.5
ACCEPTABLE 1.5 - 2.5
EMERGENCY CONDITION ONLY .5 - 1.5
UNFLYABLE 0 - .5
3.5 G
1 G
MINIMUM SATISFACTORY
PILOT RATING
0 1 2 3 4
0 2 4 6 8 10 12 14 16 18
$|P|_1 / |P_{ss}| \sim$ %

Fig. 9. Variation of pilot rating with $|p|_1/|p_{ss}|$.

tions is shown in Fig. 9. The points on this plot represent the pilot rating of the lateral maneuvering characteristics resulting from various levels of directional stability and damping, roll damping, and lateral control rolling and yawing moments.

The division between satisfactory and unsatisfactory conditions (pilot rating = 2.5) indicates that ratios of $|p|_1/p_{ss}$ up to 4.5 per cent are satisfactory. Larger values, up to approximately 8.5 per cent, represent a region of acceptable characteristics, while the unflyable limit is reached at approximately 18 per cent. It is of interest to note that the pilot rating decreases sharply in the region between 5 and 9 per cent, indicating that a relatively small increase of $|p|_1/p_{ss}$ over the specified boundary will cause significant deterioration of the characteristics. For specification purposes it is sufficient to state that the parameter $|p|_1/p_{ss}$ should not exceed 4.5 per cent as indicated by this study.

A possible application of this proposed criterion which is convenient for studying the detail requirements in terms of the basic aerodynamic parameter is indicated in Fig. 10. The boundaries shown in terms of the lateral control characteristics N_δ/L_δ are defined by the combination of the directional stability (N_β), the directional damping ($-N_r - Y_\beta$), and the lateral control characteristics (N_δ/L_δ), for which the oscillatory to steady-state roll parameter is equal to $4^1/_2$ per cent. The oscillatory boundary included in the figure is simply defined by the values of the damping and stability which satisfy the previously discussed $K/T_{1/2}$ boundary for a given value of dihedral effect. This type of approach will help orient the designs of aircraft regarding aerodynamic and control configurations, artificial damping, and stability augmentation requirements.

Conclusions

From the preceding discussion, the following two conclusions may be drawn:

(1) The lateral-directional Dutch roll requirement is better defined by the parameter $K/T_{1/2}$. For periods of oscillation shorter than 2.4 sec., the damping is equivalent to present military specifications. For higher periods, the proposed requirement is more restrictive.

(2) The use of a lateral-directional maneuvering criterion, which would limit the oscillatory roll rate per unit of steady-state roll rate to 4.5 per cent, would better ensure pilot acceptance of the lateral handling qualities and would be useful as a tool to orient aircraft design.

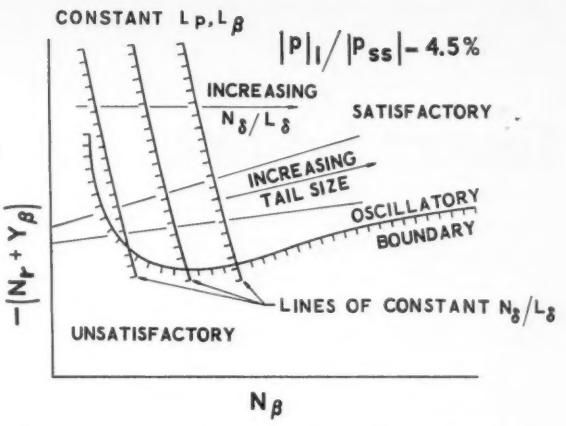

Fig. 10. Application of maneuvering flight criterion to hypothetical airplane.

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Support Systems: Part II—State of the Art

E. Wesley Landsman, *The Martin Company*

THE BASE OR support system for an ICBM or IRBM in the rapidly advancing science of missilry requires far better equipment than was ever manufactured for commercial consumption or even for aircraft support. Some of the reasons for these stringent requirements are discussed in this article.

The defensive value of any missile is lost if it is not in instant readiness in the event of attack. Its success is therefore dependent on the following capabilities of the complete missile system:

(1) The missile and its base system must be capable of standing ready for the period of time necessary to (a) improve the state of the missile art, and (b) replace the outdated missile with a better unit.

(2) The base or support system must provide all factors of ground operation to guarantee that the missile will be capable of launch at the time and place stipulated by the command.

(3) The entire system must be maintained with minimum manpower and spares backup.

These ends were achieved in present missile systems only through intensive study and development of the various subsystems and evolution of entirely new concepts in some areas. The major problems in developing base systems for handling, supporting, and maintaining the ICBM and IRBM seem to originate from their tremendous size. Complicating the situation is the fact that they are launched from stationary platforms required to withstand larger forces than any thought of before the ICBM or satellite age.

Launch Control

The system used to hold the missile in the proper alignment with the established plumb line until the required instant of release is called launch control. Launch control equipment comprises the electrical, electronic, and mechanical equipment portion of the ground operating equipment required to support, restrain, and release the missile. It consists of command and display consoles, racks of electronic equipment, interconnecting cabling, hydraulic systems, mechanical systems, and other gear. New concepts of display equipment have been advanced to conserve panel space.

Mr. Landsman, Group Engineer, Base Technical Operations Dept., attended Newark College of Engineering at Newark, N.J., where he majored in electrical engineering. Now a Group Engineer at Martin-Denver in ground systems documentation, he pioneered in liquid propellant rocket ground support design at Reaction Motors during the development of the XS-1, Lark, and Viking engines. He was employed by Bendix Aviation, Eclipse-Pioneer Division, from 1951 to 1955 as Projects Group Supervisor of service test equipment, then served as Supervisor of Service Test Equipment for Bendix, Utica Division, until 1957. Mr. Landsman is a member of the Denver Metropolitan Chapter, as well as the Colorado state and national societies, of Professional Engineers.

Indicators do not merely indicate—they also switch, interlock, and terminate. The art of missilry was fortunate in evolving at the time when transistors and semiconductors were reaching the production phase of development. The various forms of printed circuitry were also sufficiently developed to make possible their use in launch control systems.

Printed circuitry and its increased ruggedness enabled installation of thousands of circuits in the space formerly occupied by a score. Programing equipment, devised in the telephone and related communication fields, could be easily adapted for use in missile ground equipment. Indeed, the art of electronics had reached an advanced state, which had evolved from the development of equipment such as radar and computers.

Checkout

Along with the advancement of the launch control system, self-contained checkout features were incorporated, which greatly facilitated maintenance. Maintenance crews now simply operate a series of switches in the "checkout mode" permitting isolation of a faulty replaceable component in the launch control equipment. After replacement, the sequence of checkout resumes at the point of fault and continues until complete.

Design Factors

At the present state of the art, the major design factors now considered are reliability and human en-

Each subsystem involved in a support system for missiles or rockets is fairly easy to design. In fact, each design is usually based on experience gained in other industries. However, support systems sometimes demand a finer degree of regulation or control and must operate in a more stringent environment than required of a normal commercial system. This article denotes some of the limitations and tolerances commonly applied to some of the major support systems equipment. Discussed are such parameters as electric power tolerances and synchronization; heating and ventilating temperature and humidity control; gaseous pressurization systems for propellant loading; cleanliness and filtration requirements for hydraulic oils, fuels, and cryogenic liquids; and limitations on size and weight for several modes of transportation. Also discussed are techniques used for automated or semiautomatic launch control equipment, including timing accuracy as well as types of umbilical connectors. It is concluded that unique and functional combinations of equipment designed using available techniques is the challenge to the aerospace support systems engineer.

gineering. Although the launch system may never be used, it must be in a constant state of readiness. This requirement places a great burden on periodic maintenance. The launch crew must have maintenance capability to the highest degree possible with the equipment skills at hand. To support this high maintenance capability, the equipment must be designed with the nearest thing to perfect reliability and with maximum operational ease. Equipment design must incorporate features to relieve the operators from fatigue, tedium, and useless effort.

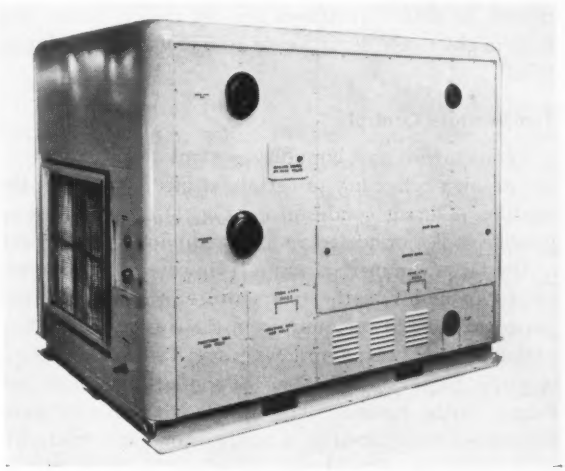


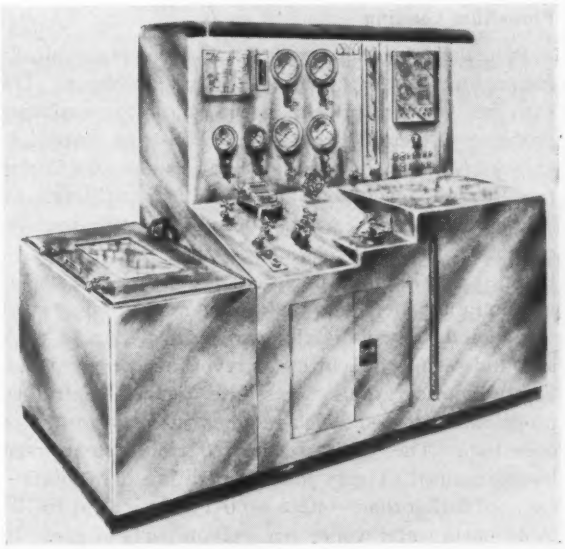
Fig. 1. Missile air conditioner.

Power

The successful operation of the electronic equipment depends on extremely well-regulated power supplies. Frequency control for power systems in the commercial frequency range is not so critical as frequency requirements for motor-driven emergency power supplies. Direct current is required for some systems in the 28-volt class with a ripple content of not more than 2.0 volts peak.

Synchronization of electronic power becomes extremely important as the complexity and magnitude of circuits increase. The launch control and checkout system with its thousands of interrelated circuits requires (1) the ultimate in impedance matching, (2) phase relationships under constant regulation, and (3) the decibel reduction of cross-talk and noise to levels compatible with signals transmitted thousands of feet by cable and waveguide.

Fig. 2. RP-1 fuel test stand.



Launcher

The launcher is the mechanical, hydraulic, and electrical system that orients the missile in proper alignment, supports it, restrains it, and launches it when signaled by the launch control system. It must respond to these signals within a definite number of milliseconds after their transmission. There is little new in concept here except that the time factor has been reduced to the point where mechanical devices cannot respond quickly enough. In some cases, electronically controlled explosive disconnects must be

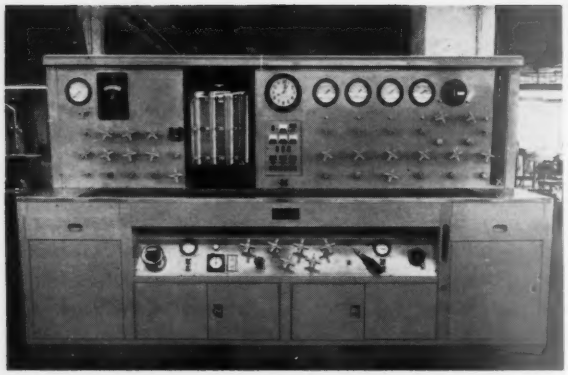


Fig. 3. Test stand, hydraulic system components.

used to achieve the results. The launcher also is required to assure clearance for all missile-borne gear that might cause deviation in course if bumped during liftoff.

Temperature Control

Temperature and humidity control are necessary to ensure high reliability of certain electronic gear on the missile. The air conditioners (Fig. 1) are designed to provide cooled or heated air at rates of flow in the ranges of the large commercial units. However, they are required to maintain the temperature of a missile compartment located remotely from the conditioner. The cooled and/or heated airflows travel through a system of ducts to the umbilical or disconnectable tube and thence to the missile. The missile compartments are sometimes maintained at a temperature to a tolerance of ± 15°F. in spite of the variations in conditions in the areas through which the ducting and umbilicals are installed.

Control of the humidity in this system is also critical in missiles containing cryogenic fuel. The humidity is maintained below a limit of 35 grains per pound of dry air.

Propellant Loading

Propellant loading systems for large cryogenically fueled missiles are beset with many problems. The extreme temperature changes cause proportionate problems in metallic expansion. Moisture content in empty lines must be maintained at a minimal value to prevent ice formation and resulting malfunctions. The cryogenic oxidizer must be loaded within minutes of launch T-O, and, because of the large quantity of liquified gas, required flow rates are established at the maximum for the design tank configuration. Design of valves and controls is therefore critical due to their size and sealing difficulties at cryogenic temperatures. Safety considerations necessitate remote control in propellant systems, which requires gas pressure motor operation. The pressurization control system must be maintained at very low temperature dew-points—e.g., not higher than −40 to −60°F., equivalent to 128 to 34 parts water vapor per million parts of gas. In some situations, helium must be used as a pressurization medium because of its extremely low liquefaction temperatures. Cryogenic fuels and systems also require filtering to assure cleanliness with particle sizes not exceeding 10 to 40 microns.

Hydraulics

The hydraulic systems required to support ICBM's are more conventional in design than most of the other missile support items. The state of the art in hydraulics has slowly advanced for many years because of the widespread industrial, automotive, and aircraft adoption of its rugged, easily controlled power output. The primary problem in missile ground hydraulics was reliability of the control system components. Under the high pressures (3,000 to 5,000 psig) used in missile servosystems to conserve weight and space, these components were subject to fluid contamination. Improvement of reliability, therefore, meant research in line and component cleaning processes before and after installation in the system. Filters with capabilities in the 10- to 40-micron range were required. Hydraulic fluids used were researched to provide operation at extreme temperatures since the fluids used in the ground operating hydraulic system had to be the same as those in the missile system.

Maintenance Test Equipment

The advancement of the art of fluid dynamics in hydraulics, cryogenics, pneumatics, and fuels generated the need for specialized maintenance test equipment. Because of the problems and hazards to operating personnel peculiar to each of these categories, the test equipment had to be designed as separate entities to be used in different areas. Hydrocarbons are not safe in the presence of liquid oxygen because of the explosive gel formed within seconds of contact. The potency of this mixture has been measured at seventeen times that of TNT when in the proper proportions and during the time cycle when at the peak of its power. Equip-

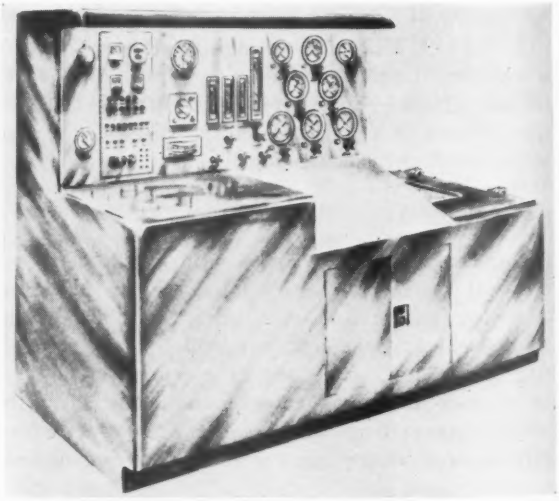


Fig. 4. Cryogenics test stand.

ment components used in or with liquid or gaseous oxygen must therefore be cleaned of every vestige of hydrocarbon contamination before being placed in service or tested under operating conditions.

High-pressure pneumatic system components and test devices are also extremely dangerous. The danger results from the rapid expansion of gases released from high pressure by the failure of the vessel or housing of the test item. Flying shrapnel from defective system components or connections to these items has been known to maim or injure operators at some distance from the test equipment. There is also the ever-present danger of asphyxiation from lack of oxygen caused by the use of inert gases under pressure. Fuel system component test stands (Fig. 2) are prone to safety problems, particularly when the fuels are toxic, flammable, and volatile—characteristics possessed by most good fuels presently used with cryogenic oxidizers.

Although fuel and hydraulic test equipment (Fig. 3) for missile ground equipment is similar to that used for aircraft ground support, the cryogenic and pneumatic requirements are unique. The cryogenic stands (Fig. 4) require the use of test mediums with characteristics matching that of the operating medium. They must also be maintained at maximum cleanliness. Pneumatic stands (Fig. 5) require the use of pressures much higher than those used in aircraft ground equipment. Working pressures of some systems in use today have static pressures of 5,000 to 6,000 psi because of the long supply and control lines used to enable safe, remote operation of missile launch gear.

Advancements must be continued in all ground support areas to keep abreast of the rapidly expanding requirements for space vehicle ground-based systems test equipment.

Handling Equipment

Handling of large missiles has become a significant item in the design of strategic missile system. The guided missile trailer with its load of a missile stage or stages should be readily transportable by ship, rail, or aircraft now in service. It should also be capable of being towed at good speeds along present highways. Exceeding these capabilities limits the strategic value of the missile in restricting its capability of dispersal and increasing its vulnerability to aggressive attack. The weight of the empty missile stage, while considerable, is no problem to rail, ship, or present large aircraft; however, when coupled with the transportation trailer and the necessary protective covers and lashings, the aspect is quite different. Extreme care is exercised in the design of the trailer to maintain the strength required to prevent undue strains occurring to the missile during transportation and to keep the size of the combined stage and vehicle within the envelope of the presently available aircraft. The guided missile trailer must also have extreme flexibility of handling and maneuverability to permit ease of loading.

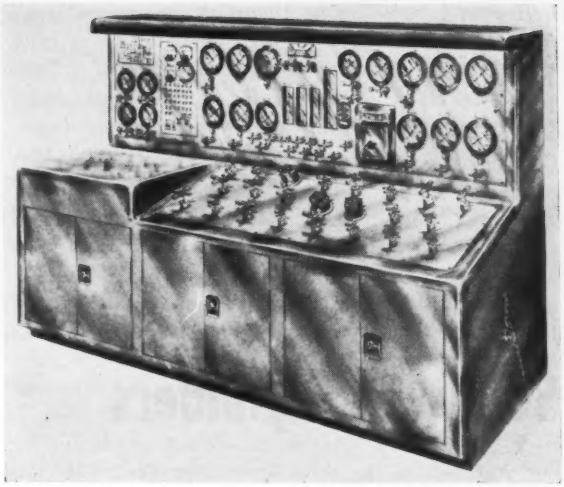


Fig. 5. Pneumatic test stand.

During the handling of the missile stages from factory to launch pad, several special devices are employed to permit attaching the hoisting means—i.e., cranes and hoists—to the missile. These devices are peculiar only because of their size and configuration and contribute little or nothing to advance the state of the art.

Timing

Timing of the phases of a missile launching operation is of the essence for a successful defensive operation. The operating crew must be trained to use properly the devices designed by the ground equipment engineer. The crew must practice both the launch techniques and the maintenance functions. The ground operating equipment and the missile must stand perpetually ready. The entire system awaits only the command.

Ground support equipment for present missile designs has kept pace with advancements in the art of missilry. Base systems will continue to grow and meet the challenge of aerospace in the increasingly complex and unique design combinations generated by new space concepts. Aerospace support systems engineers must meet the challenge with continual advances to improve reliability, reduce cost, and improve safety and human factors of designs in present systems, while developing the expanded art to cope with entirely new concepts of space vehicles not conceived at this writing.

✦ ✦ ✦

In Part I, published in August, various conventional types of cylindrical construction were compared for reliability and efficiency under several types of loading. The growth and nature of fatigue failures were discussed and correlated to hoop stress and stiffening ratio when honeycomb was used as a core.

In Part II, data are presented to illustrate the importance of uniform mechanical properties in the core by use of normal-expanded and overexpanded core construction. A solid shell was also tested for comparative purposes. Theoretical and test results are correlated.

Further improvements could be afforded by a radial core that would readily assume a cylindrical shape and retain uniform mechanical properties through the entire structure.

Sandwich Cylinders

Part II—Uniformity of the Mechanical Properties of the Core

M. I. Kazimi, Hexcel Products Inc.

SANDWICH CONSTRUCTION results in a composite structural element having a higher strength-weight ratio than can be obtained through the use of a single homogeneous material. Its major fields of application are in the structures of aircraft and missiles, where weight is the prime factor.

With the increased use of sandwich construction has come an increased need for reliable design data. Much work of both theoretical and experimental nature has been done in an effort to provide the needed information.

In the theoretical work, isotropic facings and orthotropic core have been assumed. The theory has further implied "uniform" mechanical properties throughout the core. However, this assumption of uniform mechanical properties of core in sandwich cylinders cannot be satisfied with any of today's core materials. The normal honeycomb cores have natural anticlastic properties (Fig. 9). This anticlasticity is responsible for the nonuniformity of mechanical properties when honeycomb core is curved to assume a cylindrical surface. The magnitude of the nonuniformity is a function of the thickness and radius of the sandwich cylinder.

Overexpanding the normal core is one of the successful methods of reducing the anticlasicity of the core. The overexpanded core will assume the cylindrical surface with only a small degree of nonuniformity. Yet the need for maximum efficiency and reliability demands the development of a core that will assume the cylindrical surface and conserve absolute uniformity of mechanical properties through the entire structure. This need can be met through a newly developed, radially oriented core in which all cell walls are flat planes and the axis of symmetry of every cell is perpendicular to its local tangent plane (Figs. 10a and 10b).

The honeycomb core will experience a change in properties as it experiences a variation in its degree of expansion. The density of core is at its highest in the HOBE* form of the core, then it decreases as the expansion progresses to a minimum value (at the nominal where the cell is an exact hexagon); beyond the nominal expansion, it will again increase. Fig. 11a is a plot of the density of the core as a function of the angle of expansion. The shear modulus of the core in both the strong and the weak direction will also experience a change as the core is being expanded from HOBE form to the normal expansion, then through to the overexpanded form. The general trend of this variation is shown in a theoretical curve in Fig. 11b. Because of the several variables of the core, the experimental values for the shear moduli and the density of the core differ slightly from the theoretical; nevertheless, the general trend is preserved.

In an effort to study the effect of nonuniformity of mechanical properties of the core on the structure of sandwich cylinders, two preliminary test programs were initiated at Hexcel. Details are discussed in test programs A and B.

* Honeycomb Before Expansion, © Hexcel Products Inc.

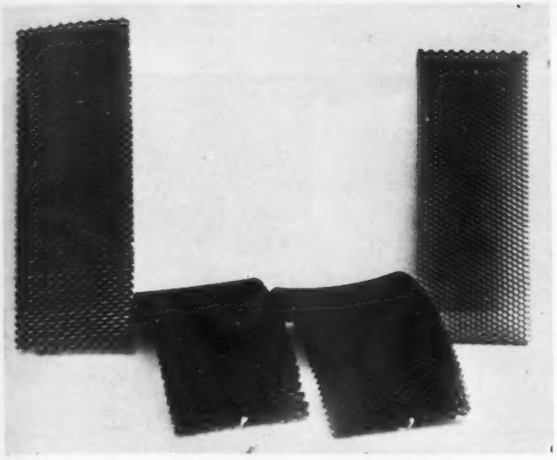


Fig. 9. Anticlastic properties of honeycomb cores. Core on left shows reduction of anticlasticity resulting from overexpanded configuration.

(A) Sandwich Cylinders Under Axial Compression

A theoretical analysis of sandwich cylinders in axial compression indicates that results fall in approximately three zones, depending on the amount of shear deformation. These zones are where there is no shear deformation in the core ($S_x = 0$), where there is some shear deformation in the core (values of S_x are small), or where there is considerable shear deformation in the core (values of S_x are large).[10]

The smallest value of S_x, at which the critical stress is determined by shear instability of the core, is greatly affected by the assumed form of the buckled shape.

The improvement in buckling stress due to the stiffness of the individual facings increases as the shear deformation increases. For small shear deformations, this improvement is negligible.

Considerable scatter in experimental values of critical stress is to be expected because of the effect of initial irregularities. Similar scatter is exhibited by solid cylindrical shells for the same reason.

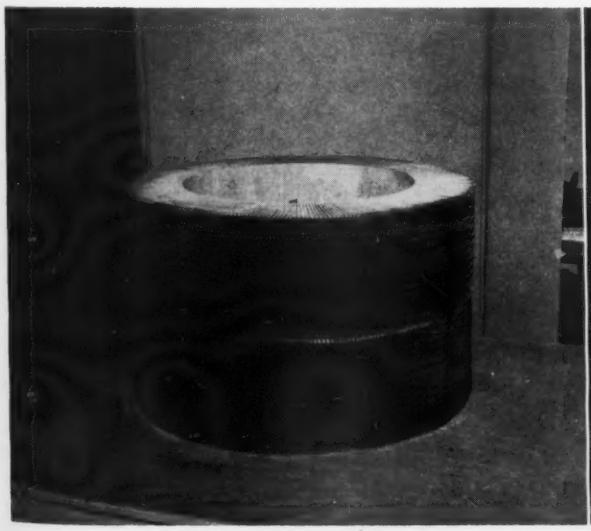
The possibility of failure by wrinkling of the facings at a stress lower than that predicted by theory should be considered. Poor facing-to-core bonding is a major cause of such wrinkling. Another factor that would initiate wrinkling is the uneven distribution of the resin that is applied to the ends of the cylinder to facilitate uniform introduction of end loads.[10]

Theory indicates that the controlling parameter in the critical buckling load is the shear modulus of the core—in particular, its reliability and constant value through the entire structure of the sandwich cylinder. The normal-expanded honeycomb core does not retain a homogeneous shear modulus through the entire cylindrical structure when formed, whereas the overexpanded honeycomb core does. It is therefore felt that cylinders made with overexpanded core will have higher buckling stress, all other things being equal.

Symbols

c	=	core thickness, in.
t	=	facing thickness, in.
$h = c + 2t$	=	sandwich thickness, in.
E	=	modulus of elasticity of facing material, psi
r	=	mean radius of cylinder, in.
σ_t	=	critical facing stress, psi
L	=	length of cylinder, in.
a	=	inner radius of cylinder, in.
b	=	outer radius of cylinder, in.
G_{rx}	=	modulus of rigidity of core associated with shear strain in axial radial plane, psi
S_x, N, Q	=	defined parameters
A_h	=	area of cross section of sandwich cylinder, in.^{2}
A_{2t}	=	area of cross section of two facings of cylinder, in.^{2}
E_h	=	compression modulus of cylinder considering A_h effective area, psi
E_{2t}	=	compression modulus of cylinder considering A_{2t} effective area, psi

Figs. 10a and 10b. Each cell of the core increases in size from the inside cylindrical surface to the outside. All walls are comprised of flat, undistorted planes for optimum performance. A separate core design must be made for each combination of cell size and cylinder size.



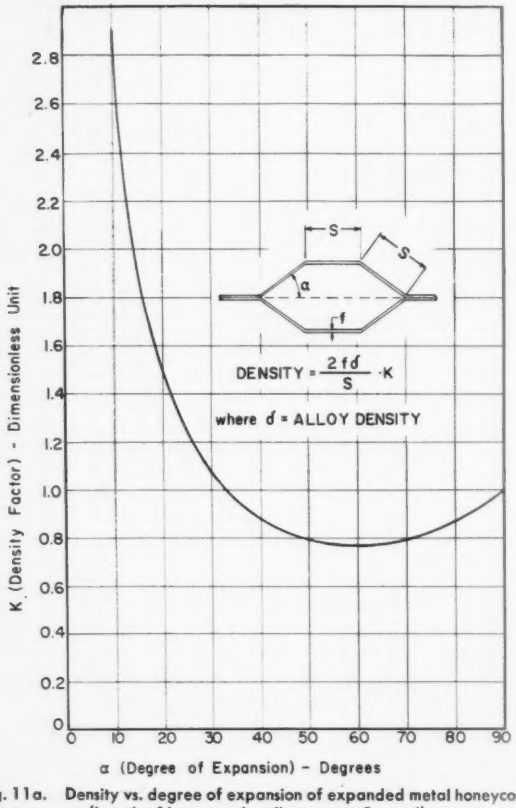


Fig. 11a. Density vs. degree of expansion of expanded metal honeycomb (length of honeycomb cell segments *S* equal).

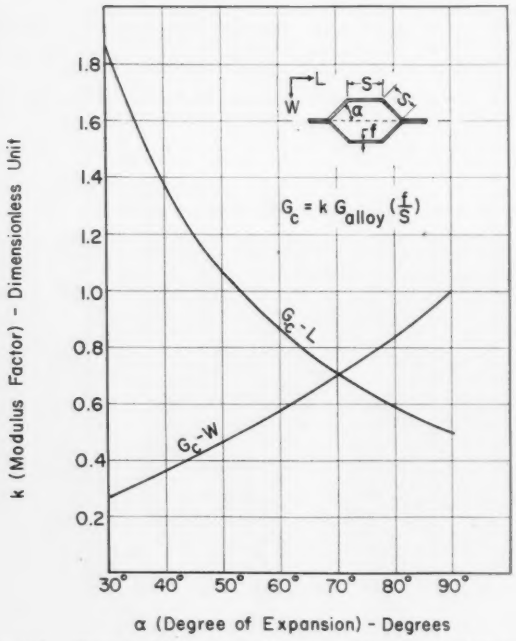


Fig. 11b. Shear modulus vs. degree of expansion of expanded metal honeycomb (length of honeycomb cell segments *S* equal).

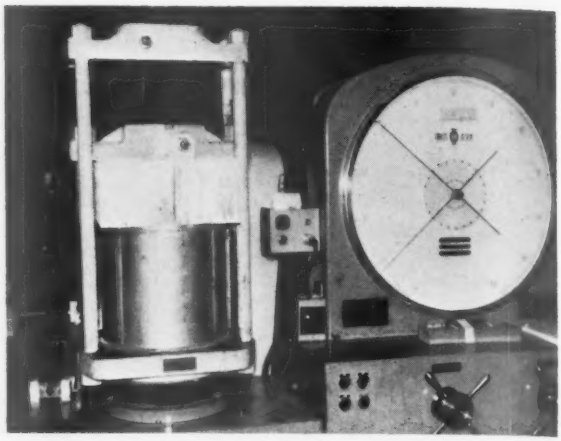


Fig. 12. Axial compression. Test on 60,000-lb. machine.

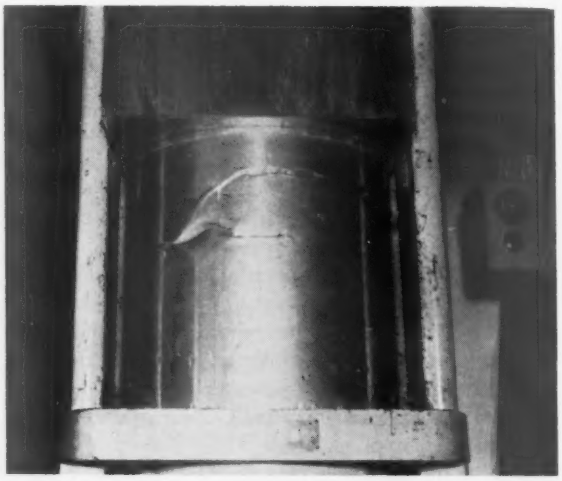


Fig. 13. Axial compression, buckling failure.

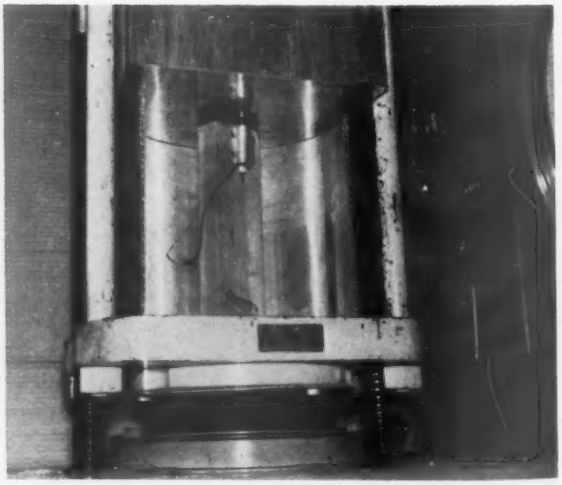


Fig. 14. Axial compression, transducer position.

Table 5.

Cylinder	Length, in.	Inside Radius, in.	Total Thickness, in.	Face Thickness, in.	Core Thickness, in.	Weight, gm.	Ultimate Load, lbs.	Drop Load, lbs.	U.L. and D.L., lbs.	Surface Deformation
O.X. #1	12.250	6.364	0.262	0.006	0.250	465	11,300	6,100	17,400	(a), (b), (c)
O.X. #2	12.250	6.364	0.262	0.006	0.250	470	14,800	3,030	17,830	(a), (d)
N.X. #1	12.250	6.364	0.262	0.006	0.250	462	12,100	2,300	14,400	(a), (b), (d)
N.X. #2	12.250	6.364	0.262	0.006	0.250	460	10,500	3,070	13,570	(a), (b), (d)
N.X. #3	10.000	6.364	0.262	0.006	0.250	..	10,800	2,100	12,900	..
Solid shell	12.250	6.364	0.020	0.020	..	470	6,580	..	..	..

(a) = surface dimples, (b) = circumferential buckles, (c) = buckles 45° circumferentially, (d) = circumferential wrinkles.

N.X. = sandwich cylinder using normal-expanded core (hexagonal cell)

O.X. = sandwich cylinder using overexpanded core (rectangular cell)

Outline of Test Program

The cylinder design used (Figs. 24 and 25) was selected in an effort to approach a typical design and to show the advantage of minimizing deformation of the core in a sandwich cylinder in axial compression. It was anticipated that a core with homogeneous mechanical properties would minimize stress concentration under axial compression and hence would yield a higher critical load.

A 1/4-in.-thick core was selected. The ribbon of the core was oriented circumferentially. A radius of approximately 6 in. was the maximum practical for testing with available equipment. All types of tested cylinders were of the same dimensions and weight in order to minimize variables and present a more valid comparison.

Aluminum alloy 5052-H38 was used for the solid shell and for the skins of sandwich cylinders. Core material KP 3/8-60 (0), overexpanded and normally expanded, manufactured by Hexcel, was selected for its low shear modulus. Edges of sandwich were stabilized with resin to allow for uniform introduction of end loads into the cylinders.

Load was applied by a Tinius Olsen hydraulic testing machine of 60,000-lb. capacity. The specimen rested directly on the base of the machine. A sandwich plate (0.090 in. Al-skins, 6 in. thick Al 1/8-3004-0.002P core) was centered on top of the cylinder, and load was applied to this through a self-aligning compression head (Figs. 12, 13, and 14).

During the test, load was applied, using a head travel rate of 0.010 in. per min. At failure, both ultimate load just prior to failure and drop load, or sustained load after failure, were recorded.

Description of Failure

O.X. #1 (Figs. 15 and 16)

At a load of 5,640 lbs., it was observed that the loading plate was in contact with a stationary section of the Tinius Olsen machine. The machine was stopped, then the load was applied again after minor adjustment of the loading plate. After completion of the test, it was observed that this adjustment resulted in an eccentricity of the applied load. The axis of the cylinder had shifted by approximately 0.2 in. from its proper location. Dimpling on the surface appeared at about 5,000 lbs. of load and was confined to one-half of the cylinder. At 10,500 lbs., dimples progressed circumferentially through the rest of the surface of the cylinder. A "crack" sound occurred at 10,000 lbs.; its origin could not be determined. Violent snap buckling occurred at 11,300 lbs. The structure was reloaded and sustained a drop load of 6,100 lbs. (See Table 5.)

O.X. #2 (Figs. 17 and 18)

Dimpling was observed clearly at a load of 7,600 lbs. and continued progressively throughout the test. It

Fig. 15. Overexpanded cylinder #1, specimen after failure.

Fig. 16. Overexpanded cylinder #1, specimen after failure.

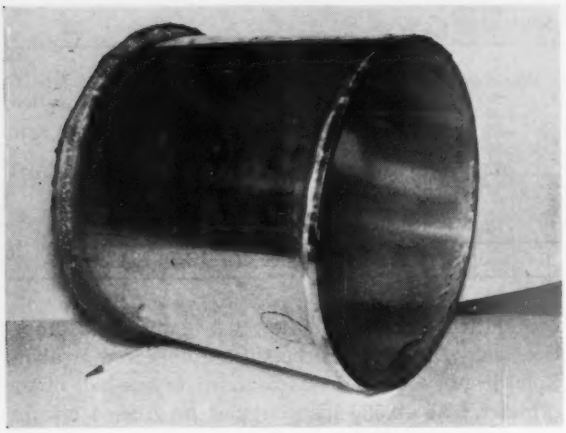


Fig. 17. Overexpanded cylinder #2, specimen after failure.

Fig. 18. Overexpanded cylinder #2, specimen after failure.

Fig. 19. Normal-expanded cylinder #1, specimen after failure.

Fig. 20. Normal-expanded cylinder #1, specimen after failure.

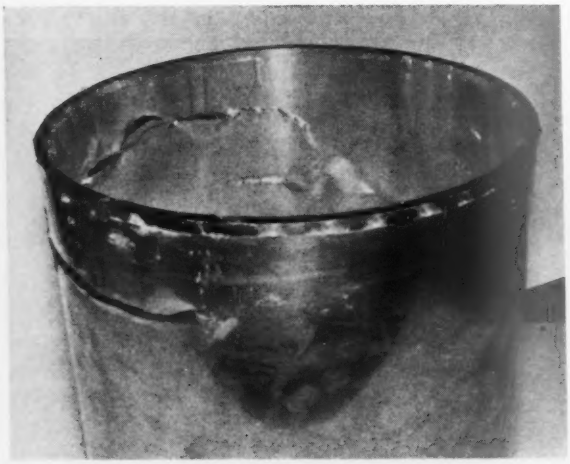


Fig. 21. Normal-expanded cylinder #2, specimen after failure.

Fig. 22. Normal-expanded cylinder #2, specimen after failure.

became very intense at about 13,000 lbs. The dimpling covered the total surface of the cylinder. A violent snap buckling occurred at 14,800 lbs. A wrinkle within one inch of the upper section of the cylinder appeared instantaneously with the snap buckling and extended over about three-fourths of the cylinder. The structure sustained a drop load of 3,020 lbs.

N.X. #1 (Figs. 19 and 20)

Dimples on the facing reached an intense stage at 9,000 lbs. and continued to increase in intensity to a load of 11,800 lbs., at which point one outward buckle occurred. A violent snap buckle occurred at 12,100 lbs. The structure sustained a drop load of 2,300 lbs.

N.X. #2 (Figs. 21 and 22)

Dimples in the facing appeared to be intense in the neighborhood of 6,000 lbs. of load. Their depth increased to a load of 9,500 lbs., at which point an outward buckle occurred. A violent snap buckle occurred at 10,500 lbs. The cylinder sustained a drop load of 3,070 lbs.

N.X. #3

The only recorded details of the test were an ultimate load of 10,800 lbs. and a drop load of 2,100 lbs.

Solid Shell

Overall buckling occurred at a load of 6,580 lbs. There were no dimples during loading or after buckling. There was no violent snap buckling.

Buckle Patterns

The buckle patterns observed during axial compression were of diamond shape, with circumferential wavelength approximately three times that in the axial direction for both cylinders with the N.X. core and the O.X. core. For a homogeneous cylinder, these wavelengths are usually approximately equal.

As for the effect on local instability of the face (dimpling) due to the altered shape of the cells, it was observed that, in the case of cylinders with normal-expanded core, the ratio of circumferential wavelength to that in the axial direction of dimples is greater than that ratio observed for dimples on the surface of cylinders with overexpanded core. However, both ratios were in the neighborhood of 3:2.

For each of the sandwich cylinders, one buckle circumferential pattern occurred in the length of the cylinder.

The following four types of surface deformation were observed.:

(a) Surface dimples	length/width $\cong$ 3:2
(b) Buckles circumferentially	length/width $\cong$ 3:1
(c) Buckles at 45° with circumference	length/width $\cong$ 2:1
(d) Circumferential wrinkle	

Buckles at 45° with circumference were present in the O.X. #1 cylinder. It is felt that this type of buckle is the result of eccentricity in loading.

Surface dimples were present in all tested cylinders.

Table 6. Compressive Modulus Data

Cylinder	$P/d \times 10^{-5}$ lbs./in.	L/A_h in.$^{-1}$	L/A_{2t} in.$^{-1}$	$E_h \times 10^{-5}$ psi	$E_{2t} \times 10^{-6}$ psi
O.X. #1	3.625	1.126	24.6	4.08	8.92
O.X. #2	3.660	1.126	24.6	4.12	9.00
N.X. #1	3.625	1.126	24.6	4.08	8.92
N.X. #2	3.640	1.126	24.6	4.10	8.95

$E_h = (p/d)\cdot(L/A_h)$; $\quad E_{2t} = (P/d)\cdot(L/A_{2t})$

Circumferential buckles were present in O.X. #1, N.X. #1, and N.X. #2. Circumferential wrinkles were present in O.X. #2, N.X. #1, and N.X. #2.

The only surface deformation in cylinder O.X. #2 (except for surface dimples) was a circumferential wrinkle extending around three-fourths of the cylinder circumference. The wrinkle was limited to the uppermost one inch of the cylinder. No other buckling patterns were visible.

Discussion of Test Results

The compressive moduli of the tested sandwich cylinders are identical, although the core changed from normal-expanded to overexpanded within the tested group (Table 6).

With either N.X. or O.X. cylinders, an increase in ultimate load results in a decrease in drop load (Fig. 23). Even more striking is the fact that the sum of the ultimate load and the drop load is approximately the same (within 5 per cent) for the two normal-expanded cylinders #1 and #2. (N.X. #3 was excluded from the comparison because of the change in length.)

If it is agreed that drop load is a measure of the remaining strength in the cylindrical structure, it can be concluded (comparing N.X. #2 with O.X. #1) that the

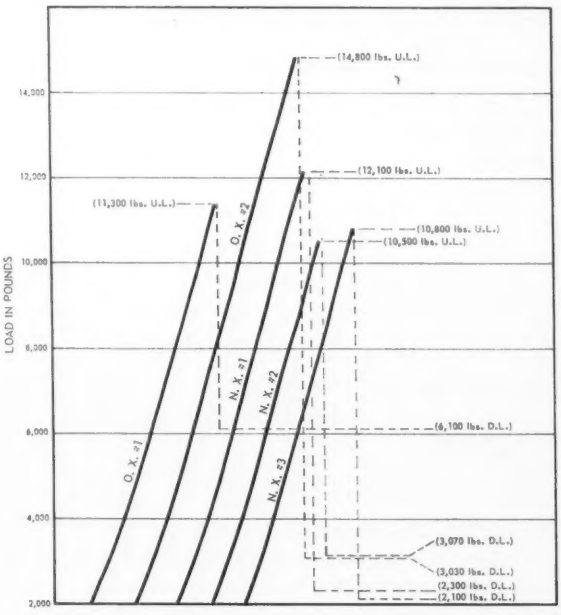


Fig. 23. Ultimate loads and drop loads of cylindrical sandwich constructions. Overexpanded honeycomb core vs. normal-expanded honeycomb core.

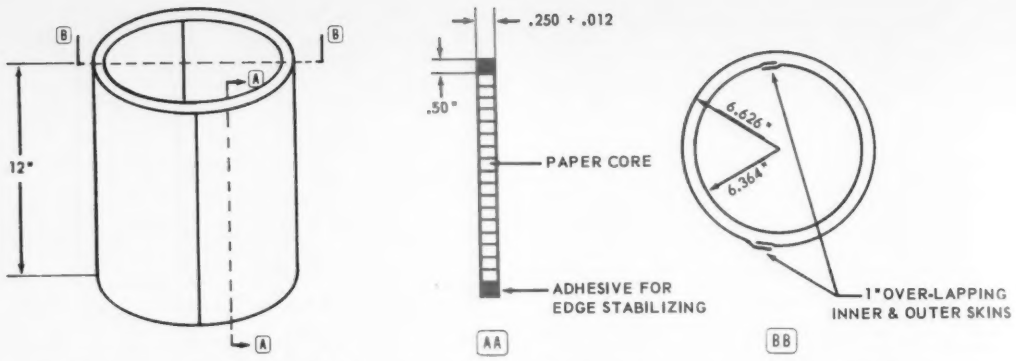


Fig. 24. Sandwich cylinder design details: Inner skin—Al 0.006 in., 12 in. by 41 in.; outer skin—Al 0.006 in., 12 in. by 42.65 in.; core—3/8 paper (60 lbs.), 11 in. by 41.65 in.

overexpanded core offers a higher buckling stress. Such a conclusion is theoretically anticipated since the magnitude of deformation in overexpanded core is smaller than in normal-expanded core when formed around the cylinder. The core with the least deformation will have the most uniform mechanical properties. The sandwich cylinder made from this core will then have less acute stress concentration region when loaded axially and will have a higher buckling stress. The aim in cylindrical construction (loaded axially) is to utilize the total available strength in the facings. This can be achieved through stabilization of the skins to prevent buckling before consuming the available strength in skins. Cylindrical sandwich construction with normal-expanded core offers an advantage over conventional shells, while overexpanded core is even more efficient. This trend leads us to postulate that specially designed, radially oriented core that will experience no deformation when formed around a cylinder will offer the highest buckling stress—possibly the optimum. Further work is needed to verify this postulation.

Correlation of Test Results With Theory

Using the Forest Products Laboratory[10] method, the following values were calculated for the different parameters:

$$\begin{aligned} G_{yr}/G_{rz} &= 0.7 \\ S_x &\cong 3 \\ c/h &= 0.96 \\ Q_1 &= 1.98 \\ N &= 0.185 \\ p_f &= 3.1 \times 10^4 \text{ psi} \end{aligned}$$

Total buckling load 15,400 lbs.

Using Gerard's method,[21] the critical buckling stress in the facing

$$\sigma_{cr} = 4.47 \times 10^4 \text{ psi}$$

and the total buckling load 22,000 lbs.

Test results indicate that overexpanded core yields values that are closest to the theoretical results. This conclusion is expected since the overexpanded core will have more uniform shear modulus over the total cylinder than the normal-expanded core. It is expected that an increase in thickness of core will magnify the superiority of the overexpanded core. Although overexpanded core appears to be superior to normal-expanded in the construction of sandwich cylinders, a specially designed radial core is expected to yield even better results. This is because it will experience no deformation and will hence approach a 100 per cent uniform shear modulus when formed as a cylinder.

(B) Sandwich Cylinders Under Uniform Lateral Pressure

Isotopic cylindrical shells under uniform pressure have been the subject of much recent study. It has been found, on various occasions, that the experimental results yield critical loads that are less than those predicted by von Mise's theory. It is the opinion of analysts that this reduction in the critical load is due to imperfections in the experimental cylinders and lower postbuckling energy levels. The second factor occurs when (a) postbuckling energy levels are reached before energy levels just at buckling, the former being reached without the necessity of passing through ("snap-through") the latter, or (b) the energy necessary for passing through the "just at buckling" level is supplied by vibration or shocks.

Sandwich cylinders are much more efficient than their solid counterparts because they are thicker; the effect of an imperfection is in proportion to the ratio of its amplitude or size to the total thickness of the shell. "Snap-through" is more likely to occur in short cylinders, and it is for the short cylinders that the stiffness of the individual facings adds a considerable amount to the critical loads.[8]

The behavior of a sandwich cylinder under uniform lateral pressure can be described by considering two overlapping stages. In the first, the cylinder remains circular and is in a state of uniform compression. In the second, the cylinder is compressed beyond a critical point and is in a state of instability that leads to buckling as pressure increases. The controlling criterion in the first stage is the uniformity of compressive modulus E_c of the core. In the second stage, and at the critical point of the first stage, the shear modulus of the core enters into the picture as another parameter influencing stability of the cylinder.

The compressive modulus of the core is measured in a nondeformed stage. When forming around a cylinder, certain types of core will exhibit a nonuniform reduction that is a function of the radius of curvature and thickness of the core; the measure of compressive modulus in such a state is unreliable.

A second type of core, such as the overexpanded honeycomb, will experience a smaller magnitude of deformation and will retain more uniform compressive modulus.

It has been verified theoretically that the influence of shear modulus in the second stage is of very small magnitude compared with the influence of compressive modulus of the core.[8]

It is felt that the core with more uniform compressive modulus after forming around a cylinder will offer a better advantage when used in sandwich cylinders under external lateral pressure.

Symbols

r, θ = polar coordinates
a = radius to middle surface of outer facing, in.
b = radius to middle surface of inner facing, in.
t = thickness of either facing when $t_0 = t_i$, in.
E = modulus of elasticity of facings, psi
μ = Poisson's ratio of facings
E_c = modulus of elasticity of core in direction normal to facings, psi
$G_{r\theta}$ = modulus of rigidity of core in r-θ plane, psi
q = intensity of uniform external lateral loading, psi
p = $-q$
σ_{rc} = normal stress in the radial direction acting in the core, psi
N_θ, N_θ' = direct stress resultants in the tangential direction in the plane of outer and inner facing, respectively, psi
K, α, β = defined parameters

Outline of Test Program

The cylinder design used (Figs. 24 and 25) was selected in an effort to approach a typical design and to show the advantage gained by minimizing deformation of core in sandwich cylinders under uniform external lateral pressure.

A core with homogeneous mechanical properties (and in particular, a uniform compressive modulus) will minimize stress concentrations under external lateral pressure, and will hence yield a higher buckling pressure.

A 1/4-in.-thick core was selected. The ribbons of the core were oriented circumferentially. A radius of approximately 6 in. was the maximum practical for testing in available facilities.

Designed cylinders were of the same dimensions and weight in order to minimize variables and present a more valid comparison.

Cylinder Construction

Details of cylinder construction are shown in Table 7.

Equipment

Hydraulic pressure tank of 14-in. inside diameter, with pressure gage and manometer vacuum pump.

Table 7. Cylinder Construction

Cylinder	N.X.	O.X.	Solid Shell
Core			
Type	KP 3/8-60-(0)	KP 3/8-60-(0)	..
Thickness, in.	0.250	0.250	..
Facing materials	0.006 in. Al foil 5052-H-38	0.006 in. Al foil 5052-H-38	0.020 in. Al foil 5052-H-38
Diameter			
Inside, in.	12.728	12.728	12.728
Outside, in.	13.252	13.252	12.768
Core to facing adhesive	Liquid epoxy resin with DTA curing agent	Liquid epoxy resin with DTA curing agent	..
Core ribbon orientation	Circumferentially	Circumferentially	..
Length, in.	12	12	12
Weight, gm.	460	465	455

Procedure

Cylinders were mounted on internal supports and end-cover plates (as shown in Figs. 26, 27, 28, 29, and 31), then enclosed in air-tight polyethylene bags. The object of the internal supports of the end-cover plates is to prevent the introduction of axial compression to the cylinders. Each cylinder was placed in the hydraulic pressure tank, and load was applied by gradual increase of water pressure.

Buckling Loads

Loads at which the pressure gage displayed a sudden drop were recorded. The buckle patterns of both types of sandwich cylinders were of the same nature and al-

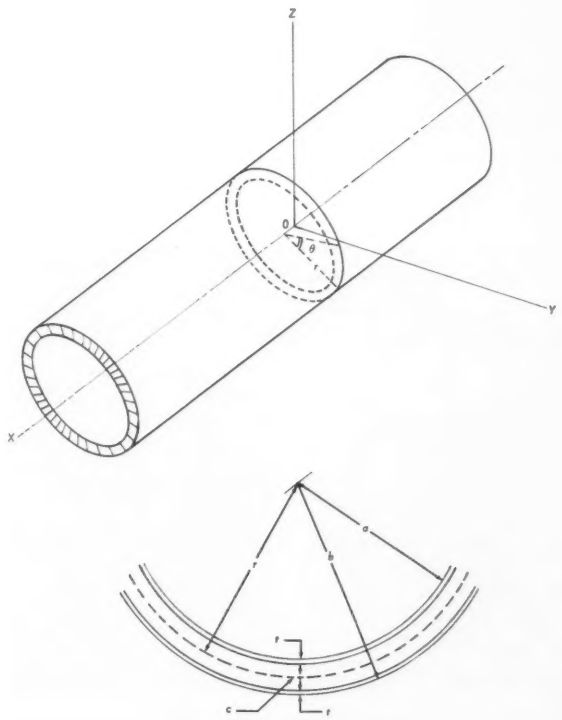


Fig. 25. Coordinate system.

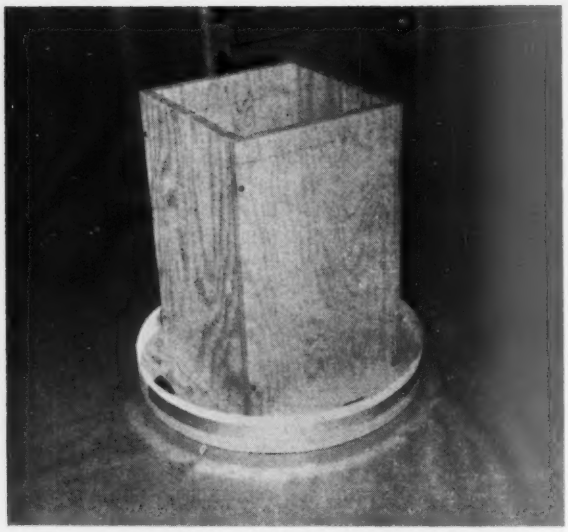


Fig. 26. External pressure, hydraulic method. View of end-cover plate and internal support.

Fig. 29. External pressure, hydraulic method. Assembled sandwich cylinder jig before being enclosed in polyethylene bag.

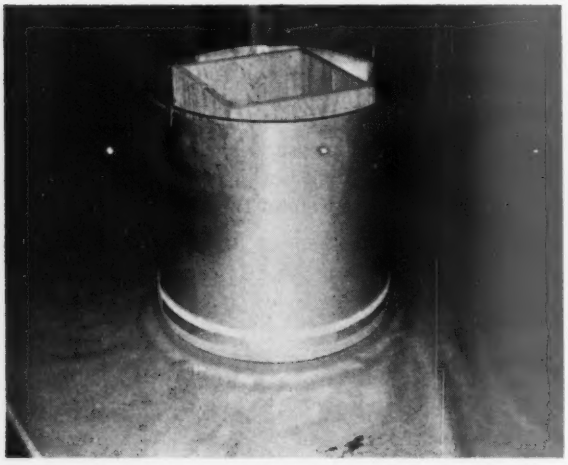


Fig. 27. External pressure, hydraulic method. Sandwich cylinder mounted over internal support.

Fig. 30. External pressure, hydraulic method. Buckled cylinder.

Fig. 28. External pressure, hydraulic method. Placement of end-cover plate on sandwich cylinder.

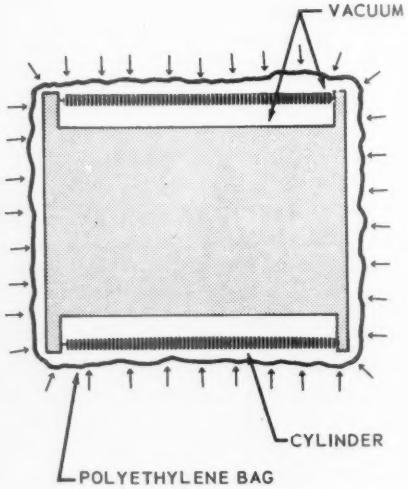


Fig. 31. External pressure, hydraulic method. Sketch of assembled cylinder jig.

most identical. A photograph of a buckled sandwich cylinder is shown in Fig. 30.

The critical load of the solid shell was 2.2 psi. That of the sandwich cylinder with the normal-expanded core was 17 psi, and that of the sandwich cylinder with overexpanded core was 27 psi.

Correlation of Tests Results With Theory

Calculated Critical Pressure

Sandwich Cylinder

The tested sandwich cylinders have the following details:

$a = 6.626$ in. $\quad c = 0.250$ in.
$b = 6.364$ in. $\quad h = 0.262$ in.
$L = 12.000$ in. $\quad t = 0.006$ in.
$\mu = 0.3 \quad E_c = 7 \times 10^3$ psi
$G_{r\theta} = 10^3$ psi

Method I

Approximate solution, neglecting p^2 in the expression for critical pressure for long sandwich cylinders

$$p_{cn} \cong 14 \text{ psi}$$

Method II

Using design curves of reference 9,

$$R/h \cong 25, \qquad c/h = 0.954 \cong 1$$

$$l/R = 1.85$$

$$V = \{E/[(1 - \mu^2)G_{r\theta}]\}(t/r) = 136$$

$$K \cong 1.5 \times 10^{-4} \text{ (from charts)}$$

Critical pressure

$$= [Et/(1 - \mu^2)h]K$$

$$\cong 36 \text{ psi}$$

Solid Shell

Critical buckling pressure

$$= 0.807 \frac{Et^2}{lr} \left\{ \left(\frac{1}{1 - \mu^2} \right)^3 \frac{t^2}{r^2} \right\}^{1/4}$$

$t = 2 \times 10^{-2}$ in.

$l = 12$ in.

$r = 6.365$ in.

$\mu = 0.3$

$E = 10^7$ psi

Critical pressure = 2.8 psi.

A comparison of calculated theoretical results with actual test results (Table 8) of buckling pressures of sandwich cylinders indicates that use of O.X. core yields results closer to theory than when N.X. is used. This conclusion is anticipated since the theoretical solution presupposes uniform mechanical properties in the core, while such uniformity is retained in different magnitudes depending on the type of core selected.

Table 8. Comparison of Results

Cylinder	O.X.	N.X.	Solid Shell
Critical pressure psi			
Calculated	36	36	2.8
Test	27	17	2.2
Compressive stress in core psi			
At $r = a$	13.5	8.5	..
At $r = b$	14	8.8	..
Hoop stress in facing at failure psi	15,000	9,400	700

Both types of cores (N.X. and O.X.) exhibit different degrees of anticlasticity. This anticlasticity is responsible for the localized irregular deformation in the core cell walls that results in nonuniformity of its mechanical properties when formed to a cylinder.

The anticlasticity of normal-expanded core is more severe than that of overexpanded when properly oriented in cylindrical construction.

An increase in core thickness or a decrease in cylinder radius will magnify the superiority of overexpanded core over the normal-expanded core.

Although overexpanded core is superior to normal-expanded core in the construction of sandwich cylinders, a specially designed radial core that will readily assume a cylindrical shape is expected to yield even better results. This is because a radially oriented core will experience no cell wall deformation when formed in cylindrical construction and will retain approximately 100 per cent uniform mechanical properties, particularly in compressive and shear moduli.

Conclusions

Isotropic facings and orthotropic core have been theoretically assumed. "Uniform" mechanical properties throughout the core have been implied by theory. However, when sandwich cylinders are made of regular honeycomb core, uniformity of mechanical properties of the core cannot be assumed. To verify this, limited testing under axial compression and uniform external lateral pressure was conducted. Two types of sandwich cylinders of the same weight, geometry, and facing characteristics (one using normally expanded and the other overexpanded paper core) and a solid shell were tested.

In axial compression tests, cylinder buckling loads of overexpanded core construction exceeded those of normal-expanded by over 25 per cent and solid shell by over 125 per cent. In uniform external lateral pressure tests, buckling pressure of the overexpanded core sandwich cylinder exceeded that of the normal-expanded core cylinder and the solid shell by proportionality factors of 1.6 and 14, respectively.

The experimental work initiated to validate the principles set forth in the report is limited. In axial compression, six tests were conducted—two on cylinders with overexpanded core, three on cylinders with normal-expanded, and one on a conventional solid shell. In external pressure, three tests were conducted, one for each type. The inevitable scatter of test results

Table 9. Buckling of Sandwich Cylinders in Axial Compression

N—Values

	$G_{yr}/G_{xr} = 0.4$				$G_{yr}/G_{xr} = 1.0$				$G_{yr}/G_{xr} = 2.5$			
S_x	c/h 1.0	c/h 0.9	c/h 0.8	c/h 0.7	c/h 1.0	c/h 0.9	c/h 0.8	c/h 0.7	c/h 1.0	c/h 0.9	c/h 0.8	c/h 0.7
0	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
0.2	0.960	0.962	0.960	0.958	0.943	0.941	0.939	0.935	0.902	0.900	0.896	0.889
0.6	0.720	0.766	0.826	0.870	0.720	0.765	0.806	0.801	0.720	0.712	0.699	0.691
1.0	0.431	0.500	0.578	0.668	0.431	0.500	0.578	0.609	0.431	0.497	0.516	0.526
1.4	0.308	0.383	0.468	0.563	0.308	0.385	0.451	0.486	0.308	0.372	0.398	0.417
2.0	0.216	0.296	0.387	0.460	0.216	0.298	0.350	0.386	0.216	0.276	0.306	0.332
3.0	0.143	0.230	0.317	0.366	0.143	0.224	0.266	0.304	0.143	0.199	0.233	0.262
4.0	0.109	0.197	0.269	0.315	0.109	0.181	0.224	0.258	0.109	0.161	0.191	0.222
6.0	0.073	0.161	0.215	0.258	0.073	0.138	0.175	0.210	0.073	0.120	0.151	0.185
8.0	0.053	0.138	0.186	0.227	0.053	0.115	0.151	0.187	0.053	0.097	0.129	0.165
10.0	0.044	0.120	0.164	0.214	0.044	0.100	0.135	0.173	0.044	0.084	0.118	0.153

may modify these values as more information is accumulated.

It is felt that further core improvement—i.e., a specially designed radial core—will result in a higher buckling load and buckling pressure. Such a core would readily assume a cylindrical shape; would, while in cylindrical form, retain approximately 100 per cent uniformity of compressive and shear modulus through the entire structure; and would generally retain all its other mechanical properties.

Appendix A: Theoretical Review

(Axial Compression)

Reference 10

For cylinders of sandwich construction having isotopic facings of equal thickness and orthotropic core such that $G_{yr}/G_{rz} = 0.4$, or $G_{yr}/G_{rz} = 1.0$, or $G_{yr}/G_{rz} = 2.5$, the critical facing stress is given by

$$p_i = (4N/5Q_1)E(h/r)$$

where

$$Q_1 = \frac{3}{2}\sqrt{\frac{5}{c^2/h^2 + c/h + 1}}$$

and N is given in terms S_x in Table 9 where $S_x = (16ctE)/(45rhG_{rz})$.

Reference 21

The normal stress in the faces at buckling is

$$\sigma_{cr} = N_{cr}/2t = k_s E[(h + t)/r]$$

where the buckling coefficient k_s is

$$k_s = \frac{\dfrac{\lambda^2(h+t)}{4(1-\mu_t^2)r} + \dfrac{r}{\lambda^2(h+t)} + \dfrac{Et}{2(1-\mu_t^2)G_c r}}{1 + \dfrac{Et}{2(1-\mu_t^2)G_r r}\lambda^2\dfrac{(h+t)}{r}}$$

where $\lambda = m\pi r/l$ and m = number of half waves along the generator of the shell.

When $E\,t/G_c r \geq 0.95$, then the value of the buckling coefficient is

$$k_s = (1/2)(G_c r/Et)$$

Under these conditions, the buckling stress

$$\sigma_{cr} = (h + t)G_c/2t$$

Appendix B: Theoretical Review

External Lateral Pressure

Long Sandwich Cylinder[8, 9]

If equal, thin facings are assumed, the stresses in sandwich cylinder under the action of a uniform external pressure q are as follows:

Normal stress (radial direction) in the core

$$\sigma_{cr} = q(a/r)K$$

Forces per unit length of facings (tangential)

$$N_\theta = qa(1 - K) \quad \text{outer facing}$$

$$N_\theta' = qaK \quad \text{inner facing}$$

where

$$K = 1/\{(1 + b/a) - (Et/E_c a)\log_e (b/a)\}$$

If the ratios $E_c\,a/Et$ and b/a are known, the value of K can be determined. Once K is known, the values of σ_{cr}, N_θ, and N_θ' are readily determined in terms of q, a, and r.

The maximum normal stress in the core always occurs at the inside surface of the core—i.e., at $r = b$.

Examination of the expression for K shows that, in general, N_θ and N_θ' are approximately equal since K is approximately equal to one-half in the practical range of dimensions and elastic constants. If E_c approaches infinity, K becomes equal to $1/(1 + b/a)$; then

$$N_\theta = q[b/(1 + b/a)]$$

$$N_\theta' = q[b/(1 + b/a)]$$

Thus N_θ and N_θ' are approximately equal if $E_c \approx \infty$ and $b/a \approx 1$, and the difference between N_θ and N_θ' increases as the core thickness increases. If $E_c \to 0$, $K \to 0$; and the external load is supported entirely by the outer facing.

The critical pressure p_{cr} is the smaller value of p among the two solutions of the following equation:

$$\left(\frac{p^2}{E_c}\right) K(1-K)\left\{\frac{4(1-b/a)^2}{(b/a)^2}+\left[\left(\frac{E_c}{2G_{r\theta}}+2\right)\left(\frac{1-b^2/a^2}{b^2/a^2}\right)+\frac{E_c\,a(1-\mu^2)}{4Et}\times\left(\frac{1+b/a}{b/a}\right)\right]\log_e\frac{b}{a}\right\}-\frac{p}{E_c}\left\{\frac{(1-b/a)^2}{(b/a)^2}\times\left[b/a-K(1+b/a)\right]+\frac{3}{4}\left[1-K(1-b/a)\right]\times\frac{\log_e b/a}{b/a}-\frac{1}{3}\left[\frac{b}{a}+K(1-b/a)\right]\left[\left(\frac{E_c}{2G_{r\theta}}-1\right)\times\left(\frac{1-b^2/a^2}{b^2/a^2}\right)+\frac{E_c\,a(1-\mu^2)}{4Et}\left(\frac{1+b/a}{b/a}\right)\right]\right\}-\frac{1}{4}\frac{(1-b/a)^2}{b/a}=0$$

A close approximation of the value of critical load p_{cr} can be obtained by neglecting the term with p^2 in the above equation. The critical pressure becomes equal to zero if either of E_c or $G_{r\theta}$ is set equal to zero.

If both E_c and $G_{r\theta}$ are taken to be infinite, the above expression for critical pressure becomes

$$p_{cr}\frac{a(1-\mu^2)}{Et}=\frac{3(1-b/a)^2}{1+b^2/a^2}$$

The value of p_{cr} from this last expression is comparable to that obtained from the formula for critical pressure on a long homogeneous cylinder if the moment of inertia used is equal to the moment of inertia of the spaced facings of the sandwich cylinder. For example, if in

$$p_{cr}=3E\,I/[r_0^3(1-\mu^2)]$$

r_0 is replaced by $(a+b)/2$ and I is replaced by $[t(a-b)^2]/2$, we then get an identical expression subject to the restrictions that $b/a \approx 1$.

Finite Length Sandwich Cylinder[8]

$$\sigma_{cr} = q(a/r)K$$
$$N_\theta = qa(1-K)$$
$$N_\theta' = qaK$$

Critical pressure p_{cr} is given by

$$\alpha_{cr}=q_{cr}\frac{a(1-\mu^2)}{Et}$$

Where α_{cr} is the lowest negative real value of α obtained from the solution of the determinant 51 (FPL 1844-B, page 23), Table 10 can be used to estimate the value of α_{cr}.

Theoretical studies indicate that, for cylinders having relatively weak cores, it is advantageous to have the stronger modulus of rigidity of the core in the tangential rather than longitudinal direction. This advantage is negligible in the case of cylinders having strong cores.

The overall stiffness properties of the core become relatively more important as cylinder length decreases.

As the cylinder decreases in length, the value of critical load *approaches* the value of $G_{r\theta}(1-b/a)$ and then falls off rapidly to zero.

If E_c is set equal to infinity, the critical load becomes equal to $G_{r\theta}(1-b/a)$ when the length becomes zero.

For cylinders having weak cores, critical pressure reaches a maximum in the neighborhood of $l/a = 1$. For those having strong cores, critical pressure continues to rise until the cylinder becomes very short.

Table 10. Approximate Values of Critical Pressure in Terms of α

b/a	0.95	0.98	0.95	0.98
$E_c/G_{r\theta}$	4	4	10	10
E_c/G_{rz}	10	10	4	4
β	1	1	1	1
λ		$-\alpha$		
0	0.00273	0.000522	0.00190	0.000432
0.25	0.00292	0.000677	0.00209	0.000586
0.50	0.00496	0.00145	0.00413	0.00114
1.00	0.00826	0.00256	0.00472	0.00179
1.50	0.010	0.0033	0.00480	0.002
2.00	0.0107	0.0040		0.00198
3.00	0.0115	0.0046		0.00196
4.00	0.0114	0.0046		
5.00	0.0110	0.0046		
6.00	0.0106	0.0046		
10.00	0.0093	0.0046		

$\beta = [E_c a(1-\mu^2)]/Et$; $\lambda = \pi a/L$

$\alpha = [q_{cr} a(1-\mu^2)]/Et$

(For accurate results, refer to tables in reference 8.)

References

(References 1–18, which applied to Part I, appeared in the August issue on pp. 37 and 46. References 8, 9, and 10, which apply also to Part II, are repeated here, along with references 19, 20, and 21 which apply only to Part II.)

[8] Raville, Milton E., *Buckling of Sandwich Cylinders of Finite Length Under Uniform External Lateral Pressure*, FPL 1844-A, FPL 1844-B, 1955.

[9] Norris, Charles B., and Zahn, John J., *Design Curves for the Buckling of Sandwich Cylinders of Finite Length Under Uniform External Lateral Pressure*, FPL 1869, 1959.

[10] March, H. W., and Kuenzi, E. W., *Buckling of Cylinders of Sandwich Construction in Axial Compression*, FPL 1830, 1957.

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Optimum Flight Profiles

(Continued from page 17)

Utilization

Figs. 1a and 2a indicate the general patterns and well-defined boundaries of the optimum flight profiles from any point in the array. In cases of results such as these, general rules for generating speed and altitude commands can be formulated and programed into an airborne computer for use in directing the aircraft in an optimum manner to a specific predetermined cruise or attack condition. The magnitude of the data storage capacity necessary to solve the optimum path dynamic programing problem virtually eliminates the possibility of performing an airborne optimum path calculation. However, with this graphic display available from the ground-based computer studies, overall flight profile patterns become immediately obvious and can be scheduled in the airborne computer in a practical form. It can also readily be seen through the use of this graphic display how the usually linearized and generalized paths and logic programed for the airborne computer either satisfy or deviate from all of the other optimum paths.

In Fig. 1b, which represents a minimum fuel climb to cruise with military power, or in Fig. 2b, which represents a minimum time climb to attack with maximum power, simple logical control laws and flight profiles are developed which attempt to optimize the flight paths from any set of flight conditions.

This graphic representation technique becomes useful not only in selecting programed and automatically controlled flight paths but also in investigating tactical operations of the aircraft from the entire performance spectrum. The program is adaptable for investigating and presenting in graphic form a series of optimizations of other parameters as previously mentioned for purposes of diving attacks, decelerating descents to base, and zoom climbs. For the purposes of this paper, only accelerating climbs have been illustrated since, historically, this category of trajectory has been most widely investigated and controlled. However, in actual applications this technique has been used by the writer to define each of the above-mentioned types of profiles as they apply to a supersonic interceptor aircraft and weapon control system. Concomitant with this graphic display is a tabular output containing quantitative data on the time, distance, and fuel consumed in following the optimum paths from each point in the array to the specified end point. In this way the qualitative graphic display can be correlated and evaluated regarding the quantitative results of following such optimum paths. In many cases where the profile-scheduling rules are not so clear cut, such a qualitative comparison of optimum vs. compromise paths is invaluable in making a decision.

In general, use of the graphic representation of the families of optimum flight trajectories greatly simplifies the programing of mission profiles and rules for command signals as required in automatic navigation, flight, and fire control systems. This technique could also be utilized to portray trajectory optimization for other systems such as satellite re-entry vehicles, etc. Specifically, in the case of manned boost-glide vehicles where the most efficient utilization of remaining energy is mandatory, this technique presents extremely attractive possibilities.

Reference

[1] Cartaino, T. F., and Dreyfus, S. E., *Application of Dynamic Programing to the Airplane Minimum Time-to-Climb Problem*, Aeronautical Engineering Review, Vol. 16, No. 6, pp. 74–77, June, 1957.

✦ ✦ ✦

Mercury Condensing Research

(Continued from page 23)

fectiveness. Either a chemical and metallurgical type of program is necessary to devise a procedure for permanently eliminating all noncondensables, or some kind of a scheme, such as a separator or relief valve, needs to be devised for ridding a system of noncondensable gases while in operation without losing the mercury working fluid.

(6) Three factors to be considered in designing a condenser tube to avoid entrapment of gases are (a) sufficiently low amounts of noncondensables, (b) sufficiently high vapor velocities, and (c) when there are no gravity forces to compress droplets to the bottom of the condenser tube, the droplets tend to cover the tube cross section and entrap noncondensables.

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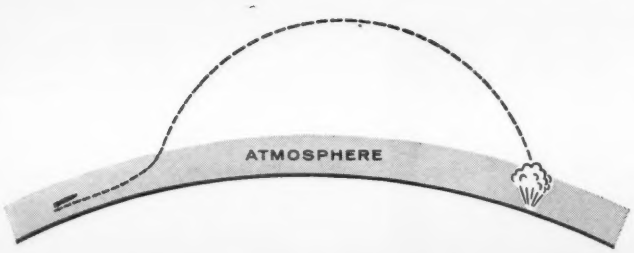

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Abe Silverstein (F), Director of Space Flight Programs for the NASA, received the honorary degree of Doctor of Humane Letters from Yeshiva University in New York June 16. Dr. Silverstein was cited for his "manifold contributions to the fields of science and to the security of our nation." Dr. Abe Gelbart, *left*, Dean of Yeshiva's Graduate School of Mathematical Sciences, and Nathaniel L. Goldstein, Chairman of the Board of Overseers of the Albert Einstein College of Medicine, set the symbolic hood in place. Dr. Samuel Belkin, *right*, President of Yeshiva, awarded the degree. (*Photo by Herbert S. Sonnenfeld*)

Continued from page 12

Harrison A. Storms, Jr. (M), Vice-President and Chief Engineer of North American Aviation, Inc., was awarded an honorary Doctor of Science degree by Northwestern University at the school's commencement on June 13.

Juan T. Trippe (A), President of Pan American World Airways, Inc., received the International Achievement Award for World Peace of the Chicago Association of Commerce and Industry in Chicago on June 23. The award, given in conjunction with the Chicago International Trade Fair, was presented to Mr. Trippe for "his unexcelled leadership in pioneering international air transportation."

James G. Wenzel (AF) has been named Coordinator of Anti-Submarine Warfare (ASW) Progrems for General Dynamics Corp. Prior to his new assignment, Mr. Wenzel was a Staff Engineer in the Office of the Vice-President, Convair, a Division of General Dynamics Corp.

Lloyd A. Wood (A), formerly Director of NASA's Office of Research Grants and Contracts, has been named Scientist for Advanced Technology in the Office of Program Planning and Evaluation.

IAS News — Corporate Member News

• **Aeronutronic Division** of the Ford Motor Co. has renamed its Range Systems Operations to Electronic Systems, and placed it under separate management from its Computer Operations.

• **Bell Aircraft Corp.** has sold its Niagara Frontier Division, Bell Helicopter Corp., and Hydraulic Research and Manufacturing Co. to Textron Inc. These units, now known as Bell Aerosystems Co., Bell Helicopter Co., and the third retaining its name, compose the **Bell Aerospace Corp.,** now a wholly owned subsidiary of Textron.

• **The Bendix Corp.** has acquired a controlling interest in Disenadores y Constructores, S.A. (Dicosa), a Mexican tool-and-die firm. The name of the company has been changed to Bendix de Mexico, S.A.

• **Fairchild Camera and Instrument Corp.** has merged with Allen B. Du Mont Laboratories, Inc., with Fairchild as the surviving company.

• **Thompson Ramo Wooldridge Inc.** has formed a new corporation in Paris to manufacture and sell its RW-300 Digital Control Computer in the European Common Market. The new firm, a part of TRW's International Division, has been named Compagnie Européenne d'Automatisme Electronique.

• **General Precision, Inc.** . . . GPL Division has moved its West Coast Sales and Service headquarters from Pasadena to 7803 Lemona Ave., Van Nuys, Calif.

• **Vitro Corp. of America** has opened a West Coast sales and service facility on Pontius Ave., Los Angeles, Calif. This new facility represents three of Vitro's divisions, Nems-Clarke Co., Vitro Engineering Co., and Vitro Labs.

IAS Sections

1960–1961 Officers

Two more sections have sent notification of their new officers for the coming season, 1960–1961.

Baltimore Section—New officers are Lester K. Fero, Chairman; Ronald G. Clanton, Vice-Chairman; James K. Marstiller, Secretary; and Lee G. Wentling, Treasurer. The Advisory Board members are Andrew McCourt, Marvin J. Kahn, William A. Bortner, James H. Bennett, Charles Poor, Stanley Corrsin, Wallace Symington, and William G. Street.

Central Florida Section—New officers are R. J. Kotowski, Chairman; G. C. Pfaff, Vice-Chairman; W. S. Roden, Secretary; and C. J. Siebert, Treasurer. Advisory Board members are R. C. Woodard, D. K. Robertson, K. R. Cossairt, R. R. Stanton, D. S. Egan, and N. N. Gough.

Atlanta Section

The Late August Raspet At April Meeting

The late **Dr. August Raspet,** Head of Mississippi State University's Aerophysics Dept., addressed the Atlanta Section's final meeting for the 1959–1960 season on April 20. Dr. Raspet's topic, **"Manipulating the Boundary Layer by Energy Conservative Means,"** included a résumé of current Mississippi State University programs on boundary layer research, and a projection of the results of these programs into the design of tomorrow's aircraft.

Dr. Raspet differentiated between energy consumptive BLC systems, and energy conservative systems which provide higher lift and lower drag by more efficient flow control. The former approach requires substantial power increments from the aircraft propulsion system, whereas the latter method yields the same performance gains with lower horsepower than required without BLC. This principle was illustrated by flight test results obtained by the Aerophysics Dept. of Mississippi State. Two new airplane designs, the Marvel and the Marvelette, were discussed in detail. These airplanes embody advances found in BLC experimentation to date by this group.

Dr. Raspet's address stimulated such lively discussion that the meeting continued for an hour and a half beyond the scheduled adjournment time.

The members of the Atlanta Section were saddened to learn of Dr. Raspet's recent death in the crash of an experimental plane. His ability, enthusiasm, and inspiration will be missed by many.

H. F. HUNTER, *Secretary*

Baltimore Section

Air Force Chief Scientist Addresses Annual Meeting

Speaking before the section's Annual Meeting for installation of officers, **Dr. Alexander H. Flax,** Chief Scientist of the

United States Air Force, discussed **"Current and Future Air Force Weapon Systems."**

Dr. Flax introduced his subject with a review of weapon system technology, wherein, such developments as radar were cited with respect to the length of time required before operational use was possible. The development of the atomic bomb was also mentioned as a demonstration of the power of research.

Pointing out that the value of science and technology in the development of superior weapons is well recognized by the military, Dr. Flax stated that the marked reduction of time between research and application has had a tremendous effect on weapons. In 1960 about 35 million dollars will be spent on basic research, while in 1935, five million dollars were spent. Applied research will be ten times that of basic research and development allocations will be three times the sum of basic and applied research.

Dr. Flax then cited the present first-line weapon systems such as the B-52 with hound-dog and sky-bolt missiles, the Atlas and Titan ICBM, and the Minute Man. For the future he mentioned the B-70, boost-glide, and orbital weapon systems. The idea was advanced that the range of technical possibilities is going to clearly outspace the economy.

The value of DynaSoar in setting the state and providing information for future systems was mentioned. Also, in the area of economics, Dr. Flax mentioned the tremendous cost of placing payloads in orbit and the importance of such developments as "recoverable boosters." He mentioned that we are just beginning to learn how to "factor-in" the reliability considerations needed in the early stages of a program. The advantages of man in the "control-link" were also cited. Further, it was mentioned that the nature of military operations in space is still obscure, but the possibility of vehicle combat in space seems likely even if space vehicles are used only for reconnaissance and inspection.

Dr. Flax concluded with the observation that we must look forward to continuous change in weapon systems as technology advances.

Following Dr. Flax's presentation, outgoing Section Chairman Dr. Andrew McCourt introduced the officers for the 1960–1961 season. Dr. McCourt was presented with a Certificate of Meritorious Service for his work as Chairman, and Dr. McCourt presented the incoming Section Chairman, Lester K. Fero, with the Section Charter and gavel.

LESTER K. FERO *Secretary*

ATTENTION IAS MEMBERS!

In accordance with plans reported in the June issue of Aero/Space Engineering, *the October, and first, issue of IAS News (prepared in newsletter format) will be published and mailed to the Institute's more than 16,000 graded members on Sept. 15 and on the 15th of each succeeding month.*

Plans to increase the technical article content of Aerospace Engineering *will take effect with the October issue, which will continue to be published and mailed on the first of each month to IAS members plus several thousand other subscribers.*

Chicago Section

Navy Hosts Meeting and Tour

Captain I. M. Hampton, USN, Commanding Officer of Glenview Naval Air Station for air reserve training, hosted the section's annual social meeting on June 2. IAS members and guests were conducted on a tour of the flight line to view reserve training equipment and air operations.

Captain Hampton delivered a welcoming address and showed documentary films pertaining to the amphibious and air support action on the part of our Mediterranean Sixth Fleet during the Lebanese incident. This was followed by a second film on the rigorous flight training schedule which the Navy's Blue Angels must adhere to in order to maintain precision flying proficiency.

N. T. GUTTENBERGER, *Secretary*

Omaha Section

TF-33 Progress Report

The June 16 luncheon meeting featured **Robert C. Baird** speaking on the **"TF-33 Turbofan Engine Development."** Mr. Baird, Chief of Military Production Engine requirements for Pratt & Whitney Aircraft Division of United Aircraft Corp., reported on the engine's progress.

The TF-33 turbofan engine was developed from the J-57. The use of this proved gas generator is the prime reason for the success this engine has enjoyed. The J-57 has accumulated some twelve million flight hours in twelve aircraft installations. Mr. Baird cited some FAA statistics which compared the J-57 with the R-2800 on the basis of unintended engine shutdown. For the R-2800 the rate is 2,825 hours and the J-57 rate is 7,934 hours. The J-57 is transformed to a fan engine by replacing the first three stages of the low speed compressor with a three stage transonic fan. Also another turbine stage was added. Fan air, that portion of the airflow through the fan not going through the high speed compressor, is exhausted through short ducts immediately aft of the fan section. The TF-33 is rated at 17,000 lbs. thrust at take-off with an SFC of 0.52. The TF-33 weighs just slightly more than the J-57 and has a specific weight improvement of 3,900 pounds over the J-57. This weight saving was accomplished by development of newer and lighter components whenever possible. The thrust of this engine is developed 50 per cent from the fan and 50 per cent from the gas generator exhaust.

Mr. Baird's remarks were of particular interest to those concerned with maintenance. The fan stages have even numbers of blades. The front fan acts as a centrifuge and will minimize foreign object damage to the high speed compressor. The fan section can be removed without tearing down the entire engine. The greatest problem associated with the TF-33 development for installation in the B-52H was the design of ducts for the two engine pods. Some fourteen configurations were tested before one design evolved that equaled and excelled the performance of the 50-50 split reference ducts. Mr. Baird stated that the TF-33 has not sacrificed the maintainability of the J-57; a mechanic trained to work on the J-57 will be able to maintain the TF-33 with a minimum of cross-training.

To date the TF-33 has accumulated some 5,300 hours of full scale testing with about 85 hours of inflight testing in a B-45 test bed. The official 150-hour test was completed in April, 1960.

MICHAEL J. MCALISTER, *Secretary*

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1960 Minta Martin Aeronautical Lecture

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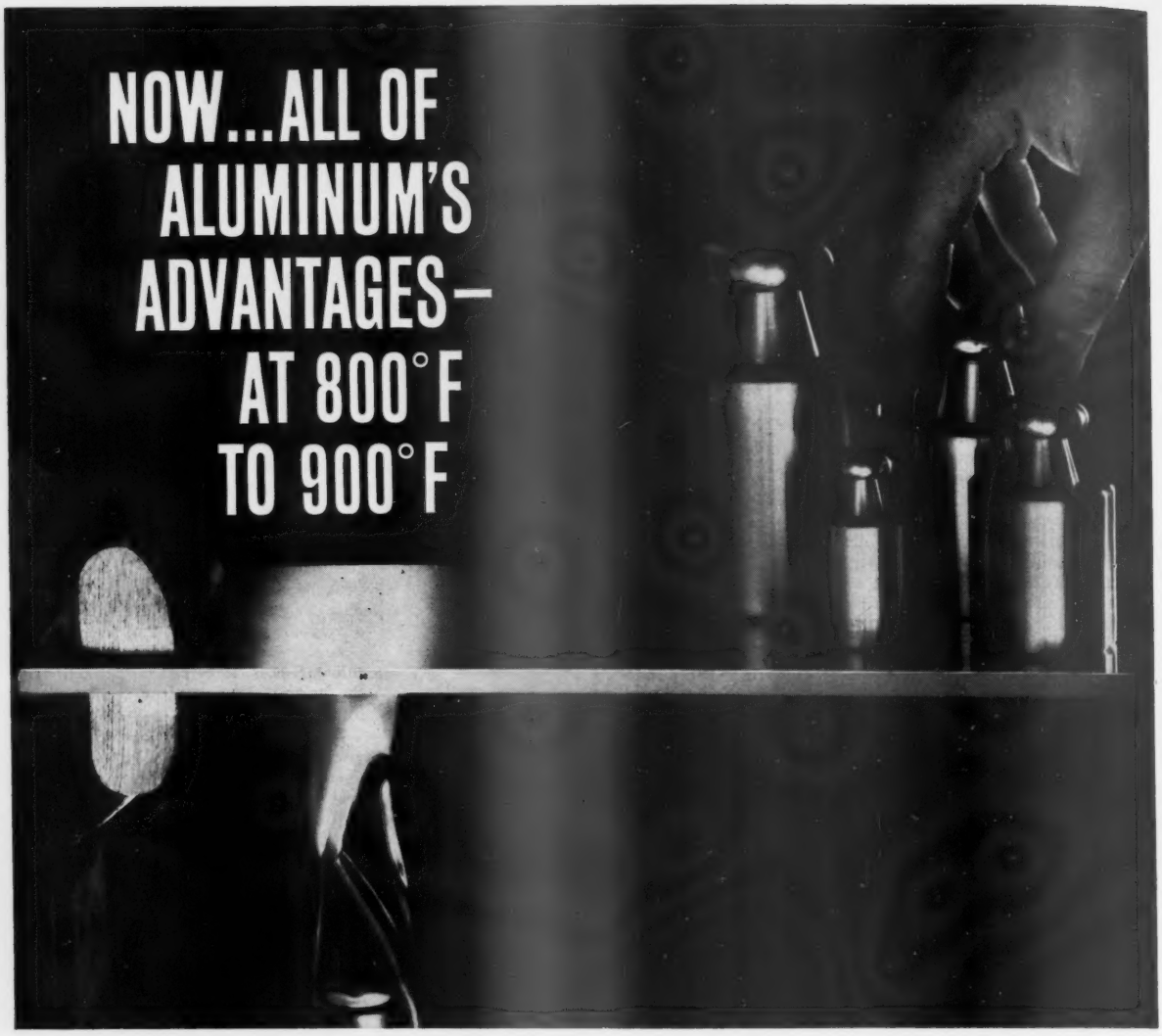

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Acoustics, Sound, Noise

Second Approximation in the Method of Smooth Perturbations. T. A. Shirokova. (*Akusticheskii Zhurnal*, Oct.-Dec., 1959, pp. 485–489.) *Sov. Phys. - Acous.*, Apr.-June, 1960, pp. 498–503. Translation. Analysis assuming that the correlation coefficient of fluctuations in the index of refraction is Gaussian in form. The form of the normalizing multiplier in the wave equation is determined.

Difraktsiia Zvuka na Periodicheskoi Nerovnoi i Neodnorodnoi Poverkhnosti. I. A. Urusovskii. *AN SSSR Dokl.*, Apr. 1, 1960, pp. 801–804. In Russian. Study of the diffraction of sound on a periodically uneven and inhomogeneous surface with a given acoustic conductivity.

Über den Lärm von Strahlantrieben und seine Verminderung. F. Staab. (*WGL Jahrbuch*, 1958, pp. 184–190.) *DFL Inst. Strahltriebwerke Bericht No. 121*, 1958. 7 pp. 13 refs. Reprint. In German. Discussion of the problem of noise generated by jet engines and survey of techniques used for its reduction.

Theory of Sound Radiation by Thin Elastic Shells and Plates. L. M. Lyamshev. (*Akusticheskii Zhurnal*, Oct.-Dec., 1959, pp. 420–427.) *Sov. Phys. - Acous.*, Apr.-June, 1960, pp. 431–438. 11 refs. Translation. Analysis yielding an integral relation connecting the radiation field with the diffraction field of the shell when the latter is free of mechanical forces. The spectral intensity of the statistical field in the case of sound radiation by cylindrical and spherical shells, as well as a thin plate vibrating under the action of statistically distributed forces, are calculated.

Fundamentals of Acoustical Silencers. III—Attenuation Characteristics Studied by an Electric Simulator. Juichi Igarashi and Masaaki Arai. *U. Tokyo Aero. Res. Inst. Rep. 351*, Feb., 1960. 31 pp.

Transient Interaction of an Acoustic Wave with a Circular Cylindrical Elastic Shell. R. G. Payton. *ASA J.*, June, 1960, pp. 722–729. Analysis considering the problem of an infinitely long, circular cylindrical elastic shell surrounded by an acoustic fluid. A plane pressure pulse, whose front is parallel to the axis of the shell, moves through the fluid, strikes the shell, and subsequently engulfs the shell.

Aerodynamics, Fluid Mechanics

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Aerothermochemistry, Dissociation, Ablation

On Hypersonic Wakes in the Atmosphere. Saul Feldman. (*Avco Everett Res. Lab. RR 82*, Dec., 1959.) *Phys. Fluids*, May-June, 1960, pp. 479, 480. Army-sponsored research.

Comparison of Transpiration and Ablation Cooling. C. C. Beusman and Joel Weisman. *ARS J.*, June, 1960, pp. 573, 574. Discussion of Scala's conclusions and extension of the calculations to include other more promising transpiration coolants—i.e., water and lithium, to illustrate the added significance of the molecular weight of the transpiration coolant, as well as the coolant heat of vaporization.

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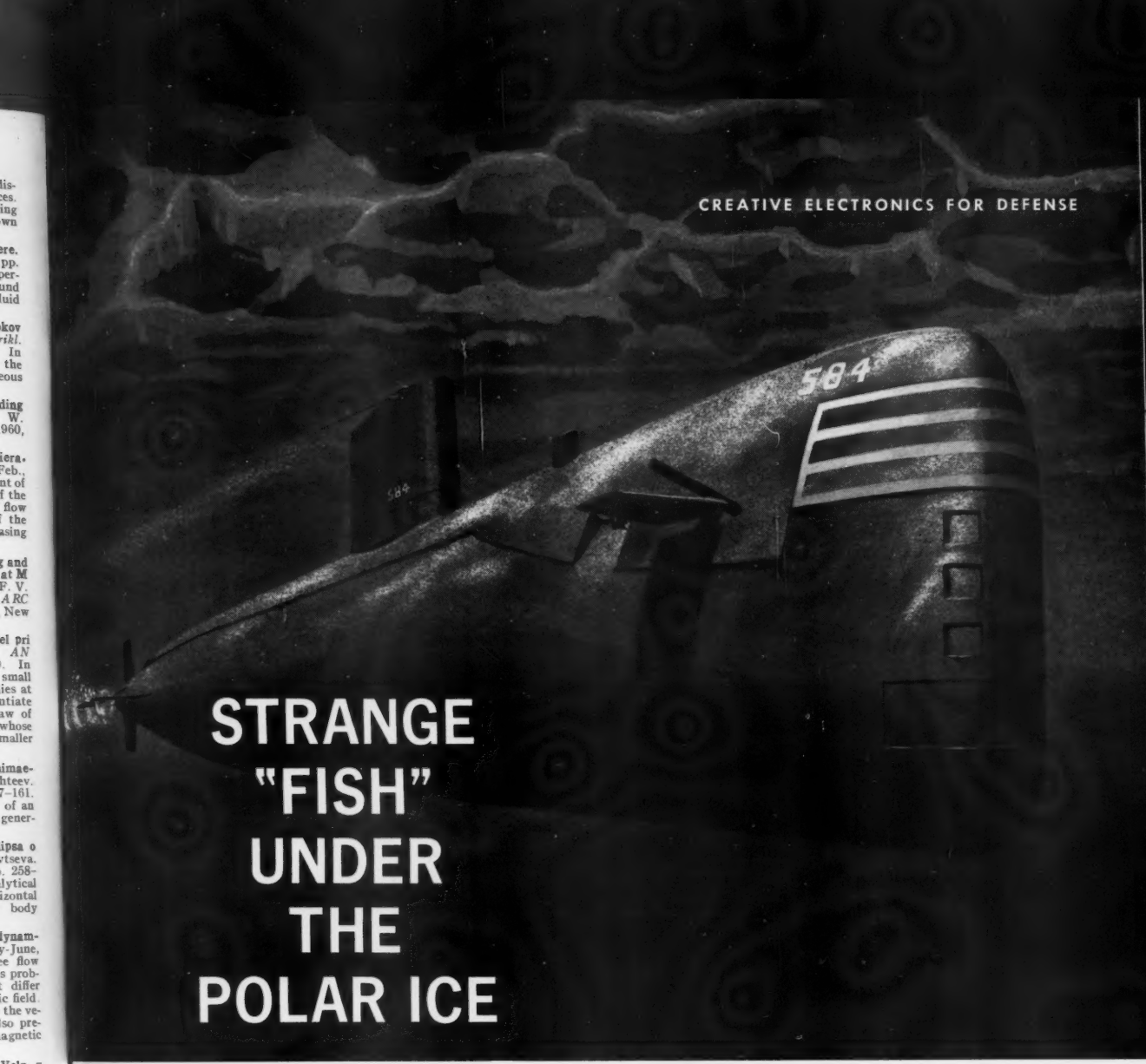

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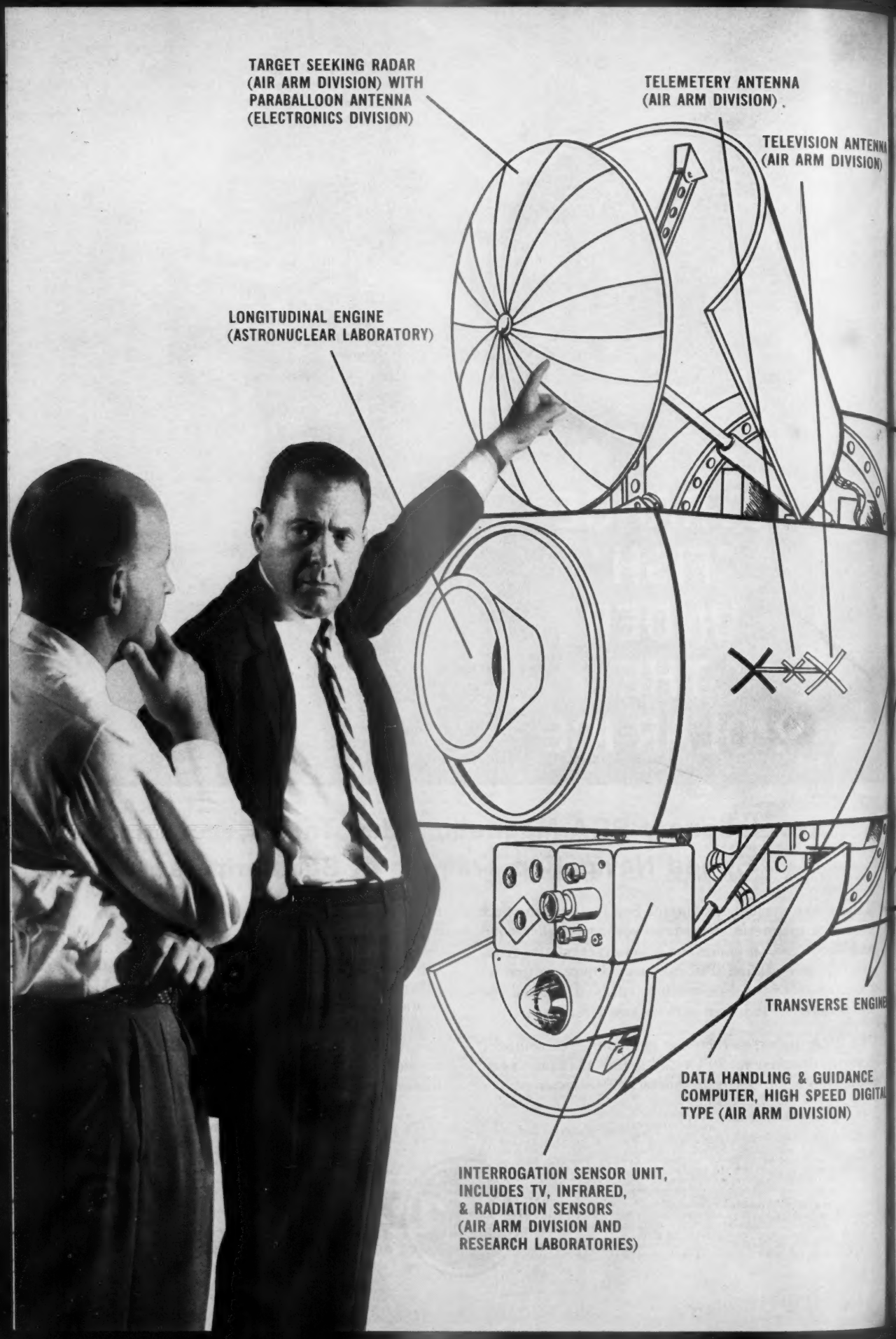
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(ASTRONUCLEAR LABORATORY)
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COMPUTER, HIGH SPEED DIGITAL
TYPE (AIR ARM DIVISION)
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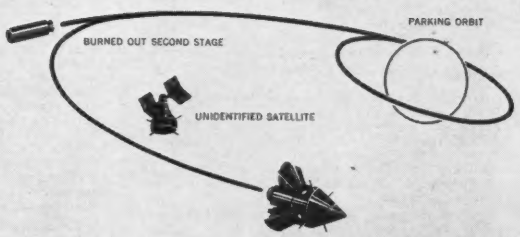

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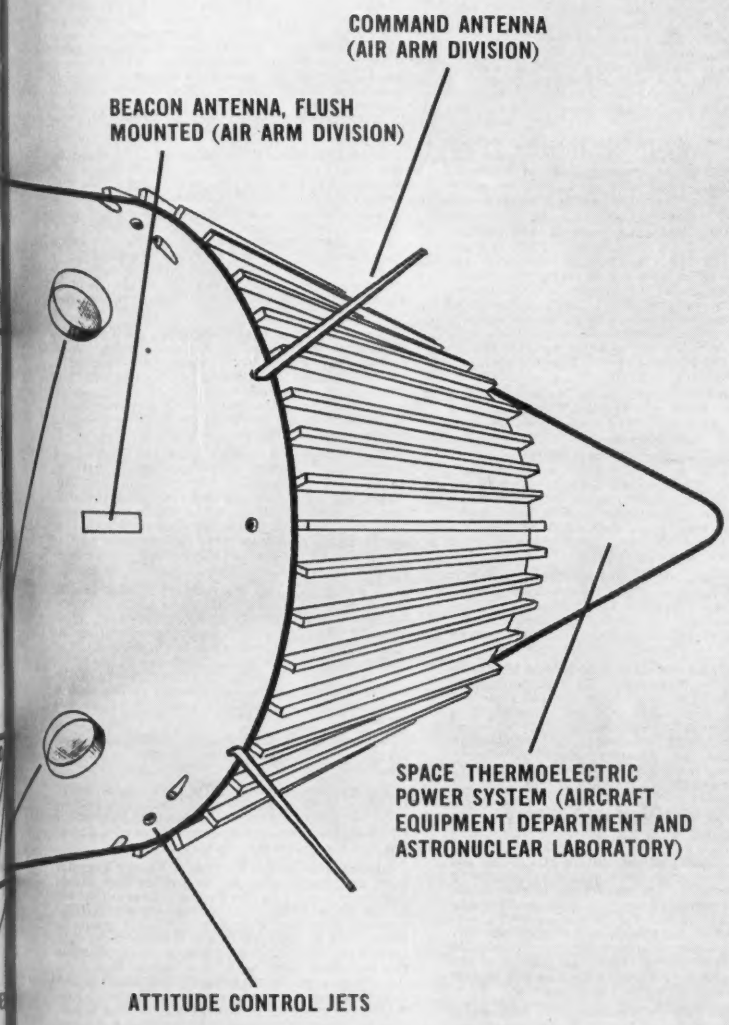

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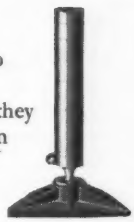

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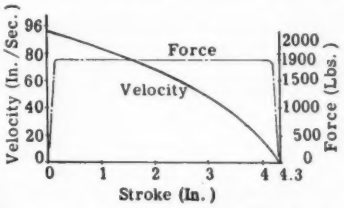

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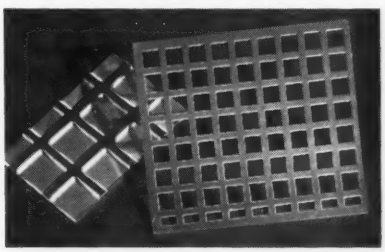

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Step and Taper Waveguide Sections with Rounded Corners. Lin Wei-Guan. *Sci. Rec.* (Peking), Mar., 1960, pp. 170–181. Investigation of the maximum electric field in the wave-guide taper section with various taper angles. It is shown that the effect of the height ratio on the magnitude of the maximum intensity is small. The properties of the step section are studied in detail, the discontinuous capacity of the step section with rounded angle is obtained, and the power-carrying capacity of taper sections is examined.

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A New Method for Space Charge Wave Interaction Studies. II. Sven Olving. *Chalmers Tek. Högskolas Handlingar, No. 228*, 1960. 43 pp. 17 refs. Extension of the theory of electromagnetic and space charge wave propagation in the resistive anisotropic medium to study the reflection coefficients at the in- and output ends of a plane traveling wave tube. The fundamentally different behavior of radially finite and infinite dense electron beams is pointed out, and the different waves which can exist in a single-velocity magneto-ionic anisotropic homogeneous resistive medium are analyzed.

Wave Theory

Special Issue: Modern Microwaves. S. P. Carter and Leslie Solomon. *Electronics*, June 24, 1960, pp. 67–86. 13 refs. *Partial Contents:* Applications. Antennas. Generators and Amplifiers. Components. Test Equipment.

Reflection of Electromagnetic Waves from a Dielectric-Magnetic Material Terminated by a Highly Reflective Material. Appendix—Power-Reflection Coefficient Graphs. E. J. Calucci. *USAF RADC TN 60-25*, May, 1960. 21 pp.

Equipment

Special Issue: Aircraft Furnishings. *The Aeroplane & Astronautics*, June 17, 1960, pp. 733–745. *Partial Contents:* Planning the Interior Layout of Air France's Caravelle, R. L. Malitte.

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An Executive Conversion. The Supporting Industry.

Pressure Sensing Actuator Speeds Wiper Reversal. J. H. Eichler. *Hydraulics & Pneumatics*, June, 1960, pp. 108–110. Discussion of the design and performance of a new hydraulic windshield wiper used on the Lockheed Electra 188. A pressure-sensing valve actuator which compares two pressures and has trigger-action valving reversal is used.

An Engineering Approach to the Rating of Aircraft Fluid Filters. J. W. Noonan. (*CAI Mid-Season Meeting, Edmonton, Feb. 19, 1960.*) *Can. Aero. J.*, June, 1960, pp. 196–202. Discussion of the function of a filter. Methods used to obtain a measure of the transmission characteristics of various filter media are described together with the necessity of obtaining accurate particle measurements. One method is presented in detail, with special reference being made to the accuracy of the results obtained.

Electric

Improved Carbon Brushes for Aircraft Electrical Machines. Appendix I—**Oscillograms of Brush Contact Drop, Rhodium-Plated Ring Investigation.** Appendix II—**Temperature vs. Time Curves, Altitude Chamber Correlation.** Appendix III—**List of Aviation Brush Materials.** R. E. Nelson. *USAF WADC TR 57-170*, Jan., 1960. 88 pp.

Applying Rotary Solenoids. Leo Orlando. *Auto. Control*, May, 1960, pp. 34–36. Discussion of the characteristics and use of various types of rotary solenoids. Application factors discussed include relative costs, size, efficiency, torque, and reliability.

F-106 Multiple Power Generating System P. W. Corbett and R. K. Walter. *Western Av.*, May, 1960, pp. 22–24, 26, 27, 42–44. Discussion of Convair's F-106 Delta Dart all-weather fighter-interceptor capable of speed in excess of Mach 2. The mission, environmental, electrical, and mechanical requirements are considered; the configuration is studied, including drive, generators, lubrication, and maintenance; pre-flight, qualification, and flight tests are discussed; and the service experience is evaluated.

Transistorized Two-Segment Commutator for a Direct-Current Machine. Appendix A—**Transistor Parameters and Symbols.** Appendix B—**Cutoff Characteristics of the Common Emitter Circuit.** Appendix C—**Design Details for the Control Flip-Flop.** Appendix D—**Design of a Trigger Pulse Generating Circuit.** D. M. P. Eisenlohr. *USAF WADC TR 59-683*, Feb., 1960. 57 pp. 31 refs.

High-Temperature Insulation for Wire. J. N. Harris and J. D. Walton, Jr. *USAF WADC TR 58-13, Pt. III*, Mar., 1960. 33 pp.

Hydraulic & Pneumatic

How to Specify and Apply Pressure and Gas-Density Switches. B. A. Hicks. *Space/Aeronautics*, June, 1960, pp. 181, 182, 186–200.

Relief Valves; Conventional vs. Inverted Type. Stanley Kowalski. *Missile Des. & Devel.*, June, 1960, pp. 64–66. Discussion of the common relief valve problems and comparison with the performance of the inverted relief valve.

Fuels & Lubricants

Jet Fuel and Safety; Some Facts About JP.4 and Kerosine. J. W. Rickard. *Flight*, June 10, 1960, pp. 787, 788, 804.

A Method for the Determination of the Limiting Oxygen Concentrations at Which Sprays Cease to Burn and Its Application to Some Hydraulic Fluids. R. F. Simmons. *Gt. Brit., RPE TN 186*, Dec., 1959. 14 pp.

An Appraisal of Synthetic Lubricants in Aircraft Gas Turbines. J. P. Perry. (*Can. Aero. J.*, May, 1960, pp. 156–163.) *Esso Air World*, May 15, 1960, pp. 148–152.

Pressure-Density-Temperature Relationship of Liquid O_2. E. A. Tkachenko. *ARS J.*, June, 1960, pp. 566–568. 12 refs. Application of two methods in conjunction with each other, one based on thermodynamics and the other on a generalized equation of state, to calculate the pressure-density-temperature relationship of liquid oxygen in the temperature range of 110°R. to 210°R., and in the pressure range of saturation conditions to 2,500 psia.

The Strain Analysis of Solid Propellant Rocket Grains. Appendix A—**Example of Viscoelastic Pressure Stresses.** Appendix B—**Example of Viscoelastic Thermal Stresses.** Appendix C—**Example of Viscoelastic Behavior Under Gravity.** M. L. Williams. (*IAS Natl. Summer Meeting, Los Angeles, June 16–19, 1959, Paper 59-110.*) *J. Aerospace Sci.*, Aug., 1960, pp. 574–586. 34 refs.

Ice Formation & Prevention

The Icing of Delta Wings of Unity Aspect Ratio Having Leading Edge Separation. C. K. Rush. *Canada, NRC Aero. Rep. LR-268*, Dec., 1959. 28 pp. Presentation of test results obtained in an icing wind tunnel with two models. The resulting ice formations are described and illustrated. The significance of scale is discussed, and it is shown that the tests are representative of icing conditions with large droplets and high speeds.

A Comparison Between the Spanwise and Chordwise Shedding Methods of Helicopter Rotor Blade De-Icing. J. R. Stallabrass and G. A. Gibbard. *Canada, NRC Aero. Rep. LR-270*, Jan., 1960. 24 pp. Discussion of flight test results obtained in an artificial icing cloud with two sets of helicopter rotor blades equipped with de-icing heater mats embodying the spanwise and chordwise shedding principles. It is shown that the spanwise shedding system has a decided performance advantage, although the chordwise shedding system has the advantage of greater constructional simplicity.

Instruments

Design of a Dual Sensor Gamma Ray Calorimeter. J. R. Coss and P. B. Hemmig. *USAF WADD TN 60-48*, Mar., 1960. 12 pp. 12 refs.

Accelerometers

The Statistical Accelerometer. P. R. Weaver. *Missile Des. & Devel.*, June, 1960, pp. 54, 55, 95. Discussion of the design and operation of a device for forecasting the possibility of structural fatigue failures.

Počítač Poryvů. Jiří Tůma. *Zpravodaj VZLÚ*, No. 3, 1959, pp. 23–25. In Czech. Description of the design, operating principles, and installation of *g*-counters.

Flight Instruments

Heading Definition in Commercial Aircraft. J. F. Green and A. P. Glenny. *Inst. Navigation J.*, Apr., 1960, pp. 196–218. 12 refs. Review of methods of defining heading and analysis of the limitations of magnetic and gyroscopic devices. Particular attention is paid to the development of the rotated race principle which is likely to be responsible for a large improvement in the basic azimuth gyro.

The Calibration and Adjustment of Aircraft Compasses. R. J. Horner. *SLAE J.*, Mar., 1960, pp. 14–20. Discussion of the earth's magnetism and aircraft magnetism and their effect on compass readings.

Verfahren zur Flugbahnvermessung. O. Weber. (*WGL Jahrbuch*, 1958, pp. 142–149.) *DFL Inst. Luftfahrzeugf. Bericht No. 119*, 1958. 8 pp. 10 refs. Reprint. In German. Summarized presentation of the essential characteristics of optical and electronic methods and instrumentation for measuring the flight paths from the ground. Several possibilities of improving the instruments and simplifying the evaluation of test values are discussed.

Flow Measuring Devices

Development of Agent Flow Measurement Methods. R. L. Hough and W. R. Kane. *USAF WADC TN 59-183*, Mar., 1960. 40 pp. Presentation of a highly refined phase-change indicator capable of measuring initial agent velocity, as well as the average agent flow rate. Other instrument ideas and techniques are discussed. Methods devised pertain not only to resolving problems in relation to fire-extinguishing systems, but also to other problems concerning transient flow in hydrodynamic systems.

Mass Flowmeters. I—Basic Types of Mass Flowmeters. II—Basic Types of Inferential Mass Flowmeters. Ch. M. Halsell. **III—A Look at Mass Flowmetering Hardware.** *ISA J.*, June, 1960, pp. 49–57.

Gyroscopes

Advances in Floated Gyro Design. W. D. Johnston and N. F. Toda. *Sperry Eng. Rev.*, June, 1960, pp. 19–25. Discussion of progress made in the development of a high-performance symmetrical rotor and integral bearing assembly, and of the application of a new general analytical technique for achieving isoelasticity.

The Floated Rate Gyroscope. G. R. Miller. *Missile Des. & Devel.*, June, 1960, pp. 43, 45. Presentation of the principles underlying gyroscopes, and description of the free gyro and the rate gyro.

The Rate-Integrating Gyro as an Aircraft Heading Reference. D. O. Fraser and J. A. Lee. *Inst. Navigation J.*, Apr., 1960, pp. 219–228. Discussion of a floated rate-integrating gyroscope and of the way in which it may be used to provide an accurate aircraft heading reference. The sources of error of the system are examined, and the overall heading accuracy is estimated as being comparable with the distance accuracy of a Doppler system.

Full-Size Performance from Subminiature Rate Gyros. Mike Levitt. *Space/Aeronautics*, June, 1960, pp. 135, 136. Discussion of design problems for a subminiature rate gyro for low dynamic ranges. Unique suspension gives performance comparable to full-size gyros.

O Privedenii Giroskopicheskogo Kompasa v Meridian vo Vremia Razgona Rotorov Giroskopov. Ia. N. Roitenberg. *Prikl. Mat. i Mekh.*, Jan.-Feb., 1960, pp. 88–92. In Russian. Discussion of a method for achieving the meridian orientation of a gyrocompass during the acceleration phase of gyro rotors.

Temperature Measuring Devices

Infrared Pyrometer Reads Engine Gas Temperature to ±20 deg R. M. C. Burrows, S. Shimizu, P. S. Myers, and O. A. Uyehara. (*SAE Summer Meeting, Chicago, June 5–10, 1960, Preprint 201 E.*) *SAE J.*, June, 1960, pp. 76, 77. Abridged. Discussion of the principles of operation and of the components of an infrared radiation pyrometer. Comparative data obtained on a specially pocketed chamber with the infrared pyrometer and velocity-of-sound instrument show that the reproducibility limits for the simultaneous measurements varied from ±20 to ±30°R. over the temperature range. Engine data recorded by the infrared radiation pyrometer for a variety of engine operating conditions are analyzed and compared with previously reported engine data obtained by other methods.

Lighter-Than-Air

Some Observations on the Wander of a Kite Balloon. M. H. L. Waters. *Gt. Brit., RAE TN Mech. Eng. 305*, Dec., 1959. 28 pp. Discussion of an investigation of the wander of a particular kite balloon to obtain estimates of balloon velocity, acceleration, and sideslip angle.

Machine Elements

Error Analysis. S. B. Tuttle. *Mach. Des.*, June 9, 1960, pp. 152–158. Discussion of a tabular method of error analysis using vector addition to evaluate system's accuracy in the early stages of design of noncontinuous systems.

Bearings

Choice of Materials is All Important for Success with High-Temp, Dry Bearings. W. J. Anderson and E. E. Bisson. (*SAE Natl. Aero. Meeting, New York, Apr. 5–8, 1960, Preprint 176D.*) *SAE J.*, June, 1960, pp. 74, 75.

High Reliability Ball Bearings. H. T. Burgess. *Missile Des. & Devel.*, June, 1960, pp. 62, 63, 73. Discussion of the steps in the design of bearings as an integral part of a machine or missile. Procedures in reliability verification and the organization of the reliability program are also presented.

Step Gas Bearings. C. R. Adams. (*SAE Natl. Aero. Meeting, New York, Apr. 5–8, 1960, Preprint 176E.*) *SAE J.*, June, 1960, pp. 29–31.

Perturbation Analysis of the Stability of Self-Acting, Gas-Lubricated Journal Bearings. Vittorio Castelli and H. G. Elrod, Jr. *Franklin Inst. Labs. Interim Rep. I-A2049-11*, Feb., 1960. 25 pp. 21 refs. ONR-supported study of the dynamics of gas-lubricated journal bearings by using Reynolds equation and the Lagrangian equations of motion. This system of equations is linearized by the perturbation method. The stability of the bearing is then investigated by studying the location in the complex plane of the roots of the characteristic determinant of the solution of the system of governing equations.

Fastenings

A Checklist on Fastener Reliability. R. L. Sproat. *Missile Des. & Devel.*, June, 1960, pp. 58–60, 110, 112.

Clamps, Mounting, for Flangeless Instrument Cases. C. S. Smith. *Gt. Brit., RAE TN I.A.P. 1114*, Sept., 1959. 15 pp.

Rotating Discs & Shafts

Stresses in Certain Thin Plates Rotating About an Axis Lying in Their Middle Plane. R. S. Dhaliwal. *Franklin Inst. J.*, June, 1960, pp. 463–473. 11 refs. Analysis applying Muskhelishvili's method to the problem of a plate having a regular curvilinear polygonal boundary. The results for circular, dumbbell-shaped, cycloidal, and cogwheel-shaped plates are derived as particular cases. The numerical results are presented in the form of tables and graphs.

Materials

Ceramics & Ceramals

The Hot Pressing of Fine Grained Ceramic Oxides for Use in Thermal Conductivity Studies. R. K. Francis, J. J. Swica, R. S. Truesdale, and J. R. Tinklepaugh. *USAF WADC TN 59-394*, Feb., 1960. 26 pp.

Preparation of Single Crystals of Silicon Carbide and Control of the Form and Amount of Included Impurities. J. A. Lely. (*Deutsche Keram. Ges. Berichte*, No. 8, 1955, pp. 229–231.) *Gt. Brit., RAE Lib. Transl. 885*, Mar., 1960. 7 pp.

Research Investigation to Determine the Optimum Conditions for Growing Single Crystals of

(Continued on page 83)

INTERNATIONAL AERONAUTICAL ABSTRACTS

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AERODYNAMICS, FLUID MECHANICS

Aerothermochemistry, Dissociation, Ablation

GENERAL RESEARCH IN FLIGHT SCIENCES - FLUID MECHANICS. I - THE EFFECT OF BODY FORCES ON MELTING ABLATION AT A STAGNATION POINT. D. M. Tellep. Lockheed Aircraft Missiles & Space Div., vol. I, Pt. I, TR LMSD-288139, Jan., 1959-Jan., 1960. 14 pp. Extension of a previous paper on stagnation region melting to remove certain restrictions placed on the variation of velocity, shear, and heat rate at the interface between the gaseous and liquid layers. Solutions are obtained numerically after applying a similarity transform. It is found that body forces caused by vehicle deceleration lead to an increase in the interface temperature and a reduction in the melting rate.

GENERAL RESEARCH IN FLIGHT SCIENCES - FLUID MECHANICS. III - FORMATION OF NITRIC OXIDE BEHIND STRONG SHOCK WAVES IN AIR. J. J. Allport. Lockheed Aircraft Missiles & Space Div., vol. I, Pt. II, TR LMSD-288139, Jan., 1959-Jan., 1960. 23 pp. 13 refs. Presentation of infrared emission studies on the formation of nitric oxide behind shock waves, carried out in a 3-in. shock tube at Mach 8 to 14. The experiments corroborate the recent analysis of Duff and Davidson, which predict that the transient NO concentration exceeds its equilibrium value. Following passage of a shock at Mach 8, the nitric oxide concentration grows slowly for 200 μ sec., and no overshoot in concentration was observed. But after passage of shocks at Mach 11 and 14, there were overshoots of 11% and 100%, respectively, of the equilibrium concentration.

GENERAL RESEARCH IN FLIGHT SCIENCE - FLUID MECHANICS. VI - SOME REFLECTED SHOCK PARAMETERS IN N_2 AND O_2. M. Scheibe. Lockheed Aircraft Missiles & Space Div., vol. I, Pt. II, TR LMSD-288139, Jan., 1959-Jan., 1960. 18 pp. Calculation of reflected shock parameters for several initial conditions in N_2 and O_2 using an IBM 704 digital computer. The solution of the shock problem is complicated by the temperature dependence of the enthalpy and free energy of the gas species at high temperatures; this is due mainly to vibrational and electronic excitation and its effect increases with increasing temperature. The most important input data for the program consist of the temperature, pressure, and molecular weights of the initial gas or gases, the equilibrium temperature behind the incident shock, and the values of the free energy and enthalpy for the species present over the range of temperature of interest.

GENERAL RESEARCH IN FLIGHT SCIENCES - FLUID MECHANICS. VII - STAGNATION-POINT HEAT TRANSFER MEASUREMENTS IN HYPERSONIC, LOW-DENSITY FLOW. S. E. Neice, R. W. Rutowski, and K. K. Chan. Lockheed Aircraft Missiles & Space Div., vol. I, Pt. II, TR LMSD-288139, Jan., 1959-Jan., 1960. 21 pp. 13 refs. Investigation of convective heat transfer associated with the phenomenon of the viscous shock layer. The experiments were undertaken to assess prior theoretical predictions by both Hoshizaki and Probstein, using the icompressible Navier-Stokes equations, that such heat-transfer rates would be greater than those predicted by the more customary boundary-layer theories. Experiments were conducted in a shock-tunnel adaptation of a combustion-driven shock tube at free-stream Reynolds numbers, based on a 1-in. nose radius, from 170 to 2, 700 and a Mach number of about 6. The test results appear to be in agreement with the theoretical predictions.

VAPORIZATION PROCESSES IN THE HYPERSONIC LAMINAR BOUNDARY LAYER. S. M. Scala and G. L. Vidale. Internatl. J. Heat & Mass Transfer, June, 1960, pp. 4-22. 55 refs. USAF-supported analysis of the phenomenon of vaporization for hypersonic flight conditions, and presentation of numerical solutions for mass transfer at the stagnation point of an axially-symmetric vehicle. The results are obtained by solving the pertinent boundary layer equations for diffusion, convection, and thermal exchange, subject to the ap-

proximate physicochemical constraints arising from the kinetics of vaporization. In addition, a universal solution is given in terms of the most significant independent parameters, which defines the flight regimes where the vaporization process is diffusion controlled, kinetically limited, or both.

TURBULENT BOUNDARY LAYER ON A FLAT PLATE IN A STREAM OF DISSOCIATING GAS. S. I. Kosterin and Yu. A. Koshmarov. Internatl. J. Heat & Mass Transfer, June, 1960, pp. 46-49. Application of the half-empirical Prandtl-Kármán turbulent theory to obtain a solution to a turbulent boundary layer problem. The method makes possible the determination of both friction and heat exchange in the flow of a dissociating gas moving at high velocities. The following is assumed: (a) Prandtl numbers of the laminar sublayer and the turbulent region of the layer are equal to unity, (b) diffusion Prandtl numbers of the two regions are also unity, (c) the wall temperature over a plate is uniform and constant, and (d) a perfect diatomic gas is assumed.

OXYGEN VIBRATION AND DISSOCIATION RATES IN OXYGEN-ARGON MIXTURES. M. Camac and A. Vaughan. Avco Everett Res. Lab. RR 84 (AFBMD TR 60-22), Dec., 1959. 80 pp. 30 refs. USAF-Army-supported investigation using an ultraviolet light absorption technique to determine the vibration and dissociation rates of O_2 in an argon-oxygen mixtures. Molecular oxygen strongly absorbs ultraviolet light radiation in a continuous broad wavelength band from about 1,350 to 1,650 Å, while atomic oxygen and argon are transparent in this region. Data were obtained over the temperature range from 1,200°K. to 8,000°K. Comparison is made with the interferometric method for the study of the oxygen relaxation rates, and the advantages of the ultraviolet absorption method are shown.

Aerothermodynamics

EFFECT OF LOCALIZED MASS TRANSFER NEAR THE STAGNATION REGION OF BLUNT BODIES IN HYPERSONIC FLIGHT. P. M. Chung. US, NASA TN D-141, May, 1960. 16 pp. OTS, $0.50. Analysis of the effect of localized mass transfer on skin friction and heat transfer for the impervious surfaces downstream of the transpiration-cooled region. Coefficients of local skin friction and Stanton numbers are calculated near the stagnation regions of a circular cylinder and a sphere for the case of localized mass transfer at the stagnation region. The numerical results obtained and an existing result for a flat plate are compared on the basis of the Blasius dimensionless fluid injection parameter. The comparison shows that the localized mass transfer becomes less effective in protecting the downstream impervious surfaces when a favorable pressure gradient is imposed on the flow and when the flow is varied from two- to three-dimensional.

THE LAMINAR DIFFUSION BOUNDARY LAYER WITH EXTERNAL FLOW FIELD PRESSURE GRADIENTS. J. R. Baron and P. B. Scott. MIT NSL TR 419 (AFOSR TN 59-1268), Dec., 1959. 67 pp. 10 refs. Analysis of a two-dimensional laminar boundary layer in the presence of foreign gas injection and a nonuniform external flow field. Similarity restrictions are given and numerical results shown for the case of helium injection into an external air flow at vanishing Mach number. The external field is described by a natural extension of the Falkner-Skan "wedge" solutions. Pressure gradients are shown to have appreciable effects upon skin friction, heat transfer, and boundary layer separation.

GENERAL RESEARCH IN FLIGHT SCIENCES - FLUID MECHANICS. II - RADIANT-ENERGY TRANSFER IN GASEOUS FLOWS. D. M. Tellep and D. K. Edwards. Lockheed Aircraft Missiles & Space Div., vol. I, Pt. I, TR LMSD-288139, Jan., 1959-Jan., 1960. 41 pp. 17 refs. USAF-sponsored review of the basic integral expressions for radiant energy transfer near a diffuse reflecting surface with uniform temperature. Conservation of energy transferred by radiation, diffusion, conduction, and convection is formulated as an integro-partial differential equation for a gray chemically reacting gas in laminar boundary-layer flow over a black wall. A similarity transform is introduced to reduce the flow equations to a pair of simultaneous, ordinary integro-differential equations, and an iterative method of solution is indicated. It is also shown that when the radiation mean free path is small compared with the thermal boundary layer thickness, introduction of the Rosseland radiation diffusion approximation reduces the energy equation to the usual form, with an equivalent thermal conductivity depending partly on the optical properties of the fluid.

GENERAL RESEARCH IN FLIGHT SCIENCES - FLUID MECHANICS. IX - INVISCID HYPERSONIC FLOW AROUND SPHERES WITH MASS INJECTION. M. Vinokur and R. W. Sanders. Lockheed Aircraft Missiles & Space Div., vol. I, Pt. I, TR LMSD-288139, Jan., 1959-Jan., 1960. 17 pp. Extension of Lighthill's constant-density solution for the inviscid hypersonic flow around spheres to include the case of mass injection from the body. It is shown that the shock-layer thickness, injection-layer thickness, and surface-pressure distribution depend only on injection momentum, for fixed free-stream conditions. The dependence is shown graphically for the case when the injection layer is irrotational.

GENERAL RESEARCH IN FLIGHT SCIENCES - FLUID MECHANICS. III - A NUMERICAL METHOD OF SOLUTION FOR HEAT CONDUCTION IN COMPOSITE SLABS WITH A RECEDING SURFACE. J. J. Brogan. Lockheed Aircraft Missiles & Space Div., vol. I, Pt. I, TR LMSD-288139, Jan., 1959-Jan., 1960. 43 pp. Presentation of numerical solutions by utilizing an explicit complete difference formulation of the heat-rate and energy-balance relations. Accuracy of the method is shown by comparison of the present results with known numerical and analytical solutions. Sample

numerical results are presented for an ablating hypervelocity vehicle, including the particular case where each material in a composite wall successively experiences the receding-surface boundary condition.

Boundary Layer

THE BOUNDARY LAYER IN A CORNER. Sin-I Cheng and R. H. Levy. Princeton U. Dept. Aero. Eng. Rep. 485 (AFOSR TN 59-1165), Nov., 1959. 45 pp. 15 refs. Analysis of the incompressible boundary layer between two semi-infinite plates whose line of intersection is parallel to the incoming flow and whose leading edges are perpendicular to it, treated for an arbitrary angle between the plates. A series expansion valid at small distances from the corner is developed; the first term is derived from consideration of the creeping flow in which convective forces are negligible compared to pressure and viscous forces. An asymptotic solution is obtained for the case when the angle between the plates is less than π; it is based upon an estimate of the form of the flow in the transverse plane far from the corner which is generally nonvanishing in the boundary layer approximation. This solution is matched to the series solution for various values of the angle between the plates, and consistent numerical results are obtained.

STABILITY OF THE COMPRESSIBLE LAMINAR BOUNDARY LAYER. Eli Reshotko. GALCIT HRP Memo. 52, Jan. 15, 1960. 156 pp. 21 refs. Army-sponsored study of previous theoretical treatments of the stability of the compressible laminar boundary layer in which the effect of the temperature fluctuations on the viscous (rapidly-varying) disturbances is either ignored (Lees-Lin), or accounted for incompletely (Dunn-Lin). A re-examination of this problem shows that temperature fluctuations have a profound influence on both the inviscid (slowly-varying) and viscous disturbances above a Mach number of about 2.0. The present analysis includes the effect of temperature fluctuations on the viscosity and thermal conductivity, and also introduces the viscous dissipation term that was dropped in the earlier theoretical treatment. Numerical examples illustrating the effects of compressibility (including neutral stability characteristics) are obtained and are compared with the experimental results of Laufer and Vrebalovich at M = 2.2, and of Demetriades at M = 5.8.

CAMBERED JET-FLAP AIRFOIL THEORY. G. R. Hough. Cornell U. Grad. Sch. Aero. Eng. Rep., Sept., 1959. 77 pp. Extension of Spence's treatment of the jet flap airfoil which used thin airfoil theory to include the effects of camber. The integro-differential equations connecting the vorticity distribution along the airfoil and the slope of the jet sheet are derived. For the particular case of a parabolic arc camber distribution, a solution in Fourier series form is obtained. The Fourier coefficients associated with incidence, jet deflection angle, and camber are calculated for several values of the jet momentum coefficient using a numerical interpolation technique. Simple expressions are obtained for the total lift on the airfoil, the chordwise loading, the jet vorticity distribution, the pitching moment, the leading edge suction force, and the jet shape.

CONDUCT THEORETICAL RESEARCH ON THE STRENGTH OF VORTICES PRODUCED BEHIND A SHOCK WAVE IN THE BOUNDARY LAYER FOR SUPERSONIC FLOW. Rudolf Bruniak. Vienna Tech. Hochsch. Final TR (EOARDC TR 60-18), 1959. 12 pp. Application of the Crocco vortex law to calculate the vortex strength behind a shock wave and to determine its influence on the thickness of the boundary layer. The velocity components of a vortex strip are calculated for several points and, from the velocity profile, the critical Mach number of each point is determined. The calculations show that the boundary layer will be lifted slightly from the wall and the gas will enter into the split opposite to the direction of the flow.

THE INFLUENCE OF THE SHOCK CURVATURE ON THE BEHAVIOR OF HYPERSONIC BOUNDARY LAYER. Antonio Ferri. Polytech. Inst. Bklyn., Dept. Aero. Eng. & Appl. Mech., PIBAL Rep. 542 (AFOSR TN 60-301), Feb., 1960. 39 pp. 15 refs. Investigation of detached and highly curved shocks and the large entropy gradients they create near the body surface, as they affect the heat transfer on the body and the transition of the boundary layer from laminar to turbulent. It is found that for moderate values of Reynolds numbers, good results can be obtained by analyzing the boundary layer with correct local stagnation conditions and by neglecting the effect of velocity gradients outside the boundary layer. For lower Reynolds numbers, boundary-layer type analysis can still be used; however, the effects of velocity gradients must be taken into account in stating the boundary conditions. The effect of vorticity in this case appears to be important.

SOME SIMILAR SOLUTIONS FOR INCOMPRESSIBLE LAMINAR BOUNDARY LAYER PROBLEMS. Koon-Sang Wan. Polytech. Inst. Bklyn., Dept. Aero. Eng. & Appl. Mech., PIBAL Rep. 538 (AFOSR TN 59-1303), Dec., 1959. 28 pp. 20 refs. Presentation of similar solutions to three types of laminar boundary layer problems in terms of known solutions. The first problem pertains to unsteady laminar boundary layer when the external irrotational flow is inversely proportional to a linear function of time and varies linearly in the direction of the main flow. The related heat transfer solution with isothermal heated surface is indicated. The second problem is the classical steady laminar boundary layer problem. The last problem is concerned with similar solutions for the boundary layer interacting with external inviscid rotational flow. A similar solution is obtained when the external vorticity is constant, large, or small.

A METHOD OF CALCULATING VELOCITY DISTRIBUTION FOR TURBULENT BOUNDARY

LAYERS IN ADVERSE PRESSURE DISTRIBUTIONS. E. M. Uram. J. Aerospace Sci., Sept., 1960, pp. 659-666, 674. 14 refs. Development of a method of calculation that permits the direct determination of the velocity profile rather than the gross integral parameters normally used to infer the general character of the boundary layer. The method provides a means of determining the total boundary-layer thickness, thus allowing calculation of the absolute as well as the nondimensional velocity distribution. The velocity profile is considered to be composed of two regions - an inner region which is described by the law of the wall and an outer region which is described by a function depicting the deviation from that law. This deviation function involves two parameters which are uniquely dependent upon the skin-friction coefficient and a third parameter which, for practical purposes, can be considered a constant. Comparison between experimental velocity distributions and those calculated by the present method shows generally good agreement.

A METHOD OF CALCULATING TURBULENT-BOUNDARY-LAYER GROWTH AT HYPERSONIC MACH NUMBERS. Appendix A - STEWARTSON'S TRANSFORMATION. Appendix B - INCOMPRESSIBLE SKIN-FRICTION COEFFICIENTS. J. C. Sivells and R. G. Payne. USAF AEDC TR 59-3 [AD 208774], Mar., 1959. 50 pp. 34 refs. Development of a method for calculating the growth of a turbulent boundary layer at hypersonic Mach numbers. Excellent agreement with experimental results from axisymmetric nozzles is obtained. The method utilizes a modification of Stewartson's transformation to simplify the integration of the momentum equation. Heat transfer is taken into account by evaluating the gas properties at Eckert's reference temperature and by using a modification of Crocco's quadratic for the temperature distribution in the boundary layer. A new empirical relation is used for the incompressible friction coefficient which agrees with experimental data over a Reynolds number range from 10^5 to 10^9.

VELOCITY AND ENTHALPY DISTRIBUTIONS IN THE COMPRESSIBLE TURBULENT BOUNDARY LAYER ON A FLAT PLATE. D. A. Spence. J. Fluid Mech., July, 1960, pp. 368-387. 19 refs. Presentation of a unified account of the distributions of velocity, shear stress, and enthalpy, starting with an examination of the set of profiles measured over a range of heat-transfer conditions at Mach numbers between 5 and 8 by Lobb, Winkler, and Persh. It is found that by plotting in terms of the Howarth variable $\eta = \int_0^y (\rho/\rho_0)dy$, the outer parts of the profiles for different Mach numbers are brought together on a single curve. By evaluating the reference density ρ_0 and the kinematic viscosity ν_0 at the so-called "intermediate" enthalpy, the inner parts of the profiles can also be collapsed, although less completely, to fit a "law of the wall." By substitution of appropriate stream functions in the equation of motion the distribution of shear stress τ in inner and outer regions is found. A relation between the distributions of enthalpy and shear stress is then found from the energy equation, using a turbulent Prandtl number α. The final expression is similar to Crocco's integral for the laminar boundary layer. The enthalpy integral is evaluated using the stated velocity-shear relation, and an expression which agrees well with available experimental data is found for the heat-transfer coefficient as a function of recovery factor and skin-friction coefficient.

A SUBLAYER THEORY FOR FLUID INJECTION INTO THE INCOMPRESSIBLE TURBULENT BOUNDARY LAYER. D. L. Turcotte. J. Aerospace Sci., Sept., 1960, pp. 675-678, 711. 18 refs. USAF-supported application of the two-region concept of the turbulent boundary layer to an injection problem. A sublayer region is introduced in which the intensity of turbulence grows at a prescribed rate. The decrease in wall shear stress due to fluid injection into the boundary layer is found under the hypothesis that the effect of injection is restricted to the sublayer region. Experimental measurements of the velocity profiles with fluid injection substantiate this hypothesis.

Flow of Fluids

ON RAYLEIGH'S PROBLEM FOR COMPRESSIBLE FLUIDS. Meir Hanin. Quart. J. Mech. & Appl. Math., May, 1960, pp. 184-198. Study of the unsteady flow generated in a viscous heat-conducting gas by an infinite flat plate set suddenly in motion in its own plane. The corresponding Navier-Stokes equations, linearized for small Mach number, are treated by operational methods and yield (1) a large-time representation of the flow, (2) a short-time representation, (3) a method for numerical evaluation of the flow at arbitrary time. The solution exhibits a transition of the flow from its short-time to its large-time form. At very short times the solution coincides with the initial-motion approximation given previously by Howarth, and is characterized by sudden initial rises in pressure and temperature. At large times the flow splits asymptotically into two distinct motions, one of which is related closely to the incompressible solution, while the other consists of an acoustic wave modified by viscosity and heat conduction.

ESTIMATION OF UNSTEADY AIRLOADS ON BLUNT BODIES IN A HYPERSONIC STREAM. I - THEORY. Haim Kennet. MIT FDRG Rep. 59-6 (AFOSR TN 59-1273), Oct., 1959. 42 pp. 19 refs. Analysis considering blunt-nosed bodies at zero angle of attack, performing small-amplitude harmonic oscillations in a main hypersonic stream. Time dependent effects are introduced as small perturbations superimposed on an approximate steady field. A power series solution yields the perturbation pressure distribution on the body. Shock amplitude and phase angle are also obtained. The results are applied to a spherical cap, in which case, the leading terms of the series solution are evaluated.

AN APPROXIMATE METHOD FOR CALCULATING THE HYPERSONIC FLOW AROUND CIRCU-

LAR CONES AT ZERO ANGLE OF ATTACK, INCLUDING REAL GAS EFFECTS. J. W. Brook. Grumman Aircraft Eng. Corp. Res. Dept. Res. Rep. RE-132, Mar., 1960. 26 pp. Development of an approximate method of calculation based on a series expansion for the velocity components in terms of the polar angle, referred to the shock wave. Two methods are devised for determining the shock wave angle and, hence, the entire flow field. Both methods are based on retaining three terms in the expansion for the radial component of velocity, an approximation which is shown to give excellent agreement with exact calculations, at least for a perfect gas. The method is developed for a perfect gas, but is shown to be easily applicable to the case of equilibrium real gas flows.

ON BASE PRESSURES AT HIGH REYNOLDS NUMBERS AND HYPERSONIC MACH NUMBERS. J. D. Whitfield and J. L. Potter. USAF AEDC TN 60-61, Mar., 1960. 22 pp. Presentation of a tentative method for estimating base pressures, considering both blunt and sharp nosed shapes. The procedure is based on existing empirical methods, but modifications are made in order to deal with short, blunt bodies. A tendency for base pressure ratios on conical or other flared bodies to increase with Mach number in the hypersonic regime is shown. This trend is dependent on body shape and is strengthened by nose bluntness. Refinement of the method depends on the receipt of experimental data covering a greater range of variables.

SYMMETRICAL SONIC FLOW ABOUT TWO-DIMENSIONAL AND AXISYMMETRIC BODIES. D. G. Randall. Gt. Brit., RAE TN Aero. 2669, Jan., 1960. 31 pp. Extension of the Oswatitsch-Keune theory of symmetrical sonic flow about bodies. The usual surface boundary condition is replaced by a more accurate one; undesirable features in the velocity distribution are thereby removed. These features occur at the nose, where the original theory sometimes predicts infinite velocities; when the modified theory is applicable it predicts zero velocity. The solution of the equation of motion then reduces to the solution of an integro-differential equation for the distribution of singularities along the line of symmetry.

THE STEADY INCOMPRESSIBLE BOUNDARY-LAYER FLOW PAST A FLAT PLATE WITH A PARABOLIC LEADING EDGE. J. Wilkinson. Quart. J. Mech. & Appl. Math., May, 1960, pp. 199-209. Solution of the full equations of motion for the steady flow of an incompressible liquid past a plate $y^2 \leqslant 4ax$, $z = 0$, when the velocity at infinite distance from the plate is of constant magnitude U and parallel to the x-axis. This solution is compared to Moore's approximate solution and is shown to be an improvement in that it behaves better outside the boundary layer. But near to the plate the solutions are in a very close agreement and give the same skin friction on the plate. It is concluded that Moore's approximate solution can be expected to give results as good as any boundary-layer solution for plates with leading edges of arbitrary shape but without discontinuities of slope.

EFFECT OF LEADING-EDGE THICKNESS ON THE FLOW OVER A FLAT PLATE AT A MACH NUMBER OF 5.7. Appendix - CALCULATION OF LOCAL TOTAL PRESSURE. M. O. Creager. US, NASA TN D-313, May, 1960. 31 pp. OTS, $1.00. Investigation of the flow field over a flat plate at a free-stream Reynolds number of 20,000 per in., for a range of leading edge thicknesses. The measured surface pressures compared unsatisfactorily with those values calculated from a linear combination of blast-wave and weak viscous interaction parameters. For thin leading edges, the boundary layer grew linearly near the leading edge. The tests were not sufficiently extensive to define the boundary layer and the shock wave near the leading edge. The boundary layer was in a high entropy layer only for the thickest plates.

SOME BOUNDARY LAYER MEASUREMENTS ON A SLENDER GOTHIC WING AT SUPERSONIC SPEEDS. R. T. Griffiths. Gt. Brit., RAE TN Aero. 2675, Feb., 1960. 22 pp. Presentation of boundary layer measurements at two positions on a gothic wing of aspect ratio 0.75. Tests were made over a range of incidence at Mach 1.42 and 1.82. With transition fixed by roughness near the leading edge, the boundary layer thickness varied little with small positive or negative incidence but was reduced at larger incidences, this being most marked at the outboard position at positive incidence due to the influence of the wing leading edge vortex. A good estimate of boundary layer thickness was given by the theory for incompressible flow over a flat plate except for positions in the vicinity of the wing vortices. The turbulent boundary layer was found to conform to a 1/5 power law.

MAGNETOHYDRODYNAMIC FLOW OF A VISCOUS FLUID PAST A SPHERE. Richard van Blerkom. J. Fluid Mech., July, 1960, pp. 432-441. Study of the flow of a viscous incompressible conducting fluid in which the uniform ambient flow field is colinear with the ambient uniform magnetic field. The force exerted on the sphere is computed for various conductivities and Reynolds numbers. Also discussed is the distinction in behavior between the flow with ambient particle speed greater than ambient Alfvén speed and that with particle speed less than Alfvén speed.

A PRELIMINARY EXPERIMENTAL STUDY OF SKIN FRICTION IN MAGNETOGASDYNAMICS. Thomas McClimans. MIT NSL TR 396, Oct., 1959. 74 pp. 20 refs. Study of the effects of magnetic fields upon the shear forces between an electrically neutral ionized gas and a vehicle surface. Magnetohydrodynamic theory is reviewed and experiments conducted with a continuous flow plasma jet for the flow of high temperature air in a circular tube are described. The friction forces were determined by pressure drops along the tube. Fluid temperatures in the experiments ranged from 6,000°R. to 8,000°R., which gave low Hartmann numbers. The feasibility of further experiments in the ionized gas region is discussed.

LINEARIZED THEORY OF AIRFOILS IN FLUIDS OF LOW ELECTRICAL CONDUCTIVITY.

S. I. Pai. G-E MSVD SSL TIS R60SD311, Dec., 1959. 27 pp. USAF-supported analysis of a uniform steady flow of compressible fluid of low electrical conductivity past thin magnetized bodies. The fundamental equations of magnetohydrodynamics are linearized, based on the assumptions of a thin body and small electrical conductivity. Because the external electromagnetic fields are under the control of the designer and independent of flying conditions, the electromagnetic fields may be used as a control device for aircraft flying in a fluid of low electrical conductivity. The effectiveness of this device is proportional to the magnetic parameter R_M.

GENERAL RESEARCH IN FLIGHT SCIENCES - FLUID MECHANICS. VII - KINEMATIC FORMULATION OF ROTATIONAL GAS FLOW. M. Vinokur. Lockheed Aircraft Missiles & Space Div., vol. I, Pt. I, TR LMSD-288139, Jan., 1959-Jan., 1960. 22 pp. Analysis showing that for the steady isoenergetic rotational flow of an ideal gas, both the specific enthalpy and the speed of sound can be expressed as functions of the velocity. As a result, it is possible to formulate the equations of motion so that the velocity is the only dependent variable. For a gas whose enthalpy and sound speed are functionally related, the results are a generalization of those for a perfect gas. If the enthalpy and sound speed are independent variables, the new formulation leads to a single vector equation whose solution completely determines the flow.

CALCULATIONS OF THE MOTION OF NONUNIFORM SHOCK WAVES. Jan Rościszewski. J. Fluid Mech., July, 1960, pp. 337-367. 13 refs. Solution of problems concerning the propagation of shock waves and strong detonation waves through ducts of variable cross section and ducts with porous walls, and the interaction of a rarefaction wave with a shock and a contact surface in one-dimensional unsteady, or two-dimensional steady flow. Tables are given that permit efficient calculation of several problems of nonuniform shock motion.

GENERAL RESEARCH IN FLIGHT SCIENCES - FLUID MECHANICS. VIII - HYPERSONIC FLOW AROUND BLUNT BODIES OF REVOLUTION WHOSE SHOCK WAVES ARE GENERATED BY CONIC SECTIONS. M. Vinokur and R. W. Sanders. Lockheed Aircraft Missiles & Space Div., vol. I, Pt. I, TR LMSD-288139, Jan., 1959-Jan., 1960. 27 pp. Extension of Lighthill's method for the special case of a spherical shock wave to the case of a family of conic shock shapes. Two approximations are required that limit the solution to the axis of symmetry. Expressions for the stagnation point values of the detachment distance, body curvature, and velocity gradient are determined and compared, for three particular shock shapes, with results from the numerical methods of Van Dyke and Mangler.

GENERAL RESEARCH IN FLIGHT SCIENCES - FLUID MECHANICS. X - THIRD-ORDER CYLINDRICAL BLAST-WAVE THEORY AND ITS ANALOGY TO THE FLOW ABOUT HEMISPHERE-CYLINDER CONFIGURATIONS IN HIGH-SPEED FLIGHT. R. J. Swigart. Lockheed Aircraft Missiles & Space Div., vol. I, Pt. I, TR LMSD-288139, Jan., 1959-Jan., 1960. 45 pp. 10 refs. Review of blast-wave theory and extension of Sakurai's work to include third-order terms in order to improve the accuracy of cylindrical theory at lower Mach numbers. Third-order shock-wave shapes about hemisphere-cylinder configurations at Mach numbers 3.27 and 7.7 are compared with the second-order solutions and experimental data. Third-order surface pressure distributions on a hemispheric cylinder are compared with the second-order solution and experimental data at Mach number 7.7 and with the second-order solution and characteristic solution at Mach number of 17.98. Third-order theory improves agreement of predicted pressure-distribution curve slopes with those determined experimentally or by theoretical numerical methods. Third-order theory is, however, somewhat less satisfactory than second-order theory for predicting shock-wave shapes.

OBLIQUE SHOCK RELATIONS FOR AIR AT MACH 7.8 AND 7200 R STAGNATION TEMPERATURE. H. T. Nagamatsu, J. B. Workman, and R. E. Sheer, Jr. ARS J., July, 1960, pp. 619-623. 10 refs. USAF-supported calculation of oblique shock relations for dissociated air in free stream flow. The results for the density, pressure, and temperature ratios, and flow deflection across the shock wave are presented as functions of the shock wave angle. Complete equilibrium is assumed in the calculations, utilizing the best available thermodynamic properties of air for the region considered. The real gas oblique shock relations have been experimentally verified by testing an adjustable two-dimensional wedge model in a hypersonic shock tunnel. Correlations of the calculated and experimental pressure ratios and shock wave angles are presented as functions of flow deflection angle. When allowance was made for the boundary layer displacement effect, the correlation was seen to be good.

SHOCK-WAVE STRUCTURE IN BINARY MIXTURES OF CHEMICALLY INERT PERFECT GASES. F. S. Sherman. J. Fluid Mech., July, 1960, pp. 465-480. 13 refs. Development of a continuum theory for steady flow of a mixture of chemically inert perfect gases through a normal shock of arbitrary strength. For shocks of vanishing strength, a solution by series expansion in Grad's shock-strength parameter gives a result essentially the same as found previously by Dyakov. For stronger shocks a straightforward numerical integration, analogous to that useful in the simpler pure-gas problem, is outlined. The resulting problem has eight parameters: shock strength, ratio of specific heats, ratio of bulk viscosity to shear viscosity, Prandtl number, Schmidt number, thermal diffusion factor, molecular mass ratio, and initial mixture concentration. A dozen examples are calculated to exhibit the influence of some of the parameters.

NUMERICAL INVESTIGATIONS ON THE SOLUTION OF THE NON-LINEAR EQUATION OF SUPERSONIC FLOW BY FINITE DIFFERENCE METHODS. I. Gerhard Seegmüller. Munich Tech. Hochsch. Math. Inst. TN 10 (AFOSR TN 60-255), Nov. 4, 1959. 45 pp. 12 refs. Development of a numerical solution of the initial value problems of plane and cylindrical symmetry for steady, irrotational, and isentropic supersonic flows of ideal gases. The basic element for the construction of the solution is the algorithm for the so-called "single mesh" which makes it possible to compute the flow in a certain fresh point by means of at least two points where the flow is already known. Information is given on the type of convergence and on the truncation error in the local case and in the large, when solving the difference equations by iteration. Pure mean-value procedures are described which also converge on the axis of flows with cylindrical symmetry.

ON THE THEORY OF HOMOGENEOUS AXISYMMETRIC TURBULENCE. III. Michio Ohji. Kyushu U. Rep. Res. Inst. Appl. Mech., No. 28, 1959, pp. 259-278. Examination of the large-scale structure and the final period of decaying homogeneous axisymmetric turbulence, based on the Batchelor-Proudman general theory. It is shown that four independent parameters appear in the relevant energy spectrum tensor and, therefore, little modification is found to be necessary for Chandrasekhar's picture of axisymmetric turbulence in the final period. Some illustrative correlation curves in this period are computed. In addition, a certain case of axisymmetric turbulence is analyzed in connection with a model proposed by Chandrasekhar which may be regarded as a noninteracting superposition of isotropic and axisymmetric fields of turbulence.

A WIND TUNNEL INVESTIGATION INTO THE PRESSURE DISTRIBUTION ON A WING SURFACE IN A NON-UNIFORM SUPERSONIC FLOW. Appendix I - THE ESTIMATION OF THE LINEAR THEORY PRESSURE DISTRIBUTION ON A WING SURFACE DUE TO AN INFINITE STRAIGHT VORTEX. Appendix II - AN APPROXIMATE CORRECTION FOR THE FINITE DISTANCE BETWEEN THE FOREPLANE AND WING SURFACE. Appendix III - THE ESTIMATION OF THE SIDEWASH VELOCITY PRODUCED BY A WING IN A FIELD DUE TO AN INFINITE STRAIGHT VORTEX BY A LINEAR THEORY METHOD. Appendix IV - AN ESTIMATION OF THE PRESSURE DISTRIBUTION PRODUCED BY A FREE VORTEX PASSING OVER AN INFINITE PLANE. M. C. P. Firmin and W. J. Bartlett. Gt. Brit., RAE TN Aero. 2673, Feb., 1960. 35 pp. 15 refs. Experimental and theoretical investigation showing that linearized theory may be used to determine the pressure distribution on a wing surface in a nonuniform flow field caused by a streamwise line vortex. It is demonstrated that a free vortex passing over a surface induces pressure and suction peaks on respective sides of the spanwise station of the vortex. These peaks are situated along Mach lines and are attenuated chordwise. It is found necessary to include the cross-flow terms in determining the theoretical pressure distribution.

Internal Flow

STARTING CHARACTERISTICS OF A CONVERGENT-DIVERGENT DIFFUSER BLADE PASSAGE OF A SUPERSONIC COMPRESSOR IN MACH THREE FLOW. V. D. Agosta and J. P. DeCarlo. Polytech. Inst. Bklyn., Dept. Aero. Eng. & Appl. Mech., PIBAL Rep. 539, Feb., 1960. 21 pp. Navy-supported investigation of the effects of three-dimensional perturbations on starting characteristics of supersonic diffuser blade passages. Four models were tested with variations in blade thickness along the radius and initial wedge angle. The results indicate that a redistribution of mass flow within the passage occurred during the starting process due to induced radial pressure gradients. Isentropic, one-dimensional contraction ratios were approached upon starting by orienting the minimum-area-plane with respect to the compressor axis.

BASE PRESSURE AT SUBSONIC SPEEDS IN THE PRESENCE OF A SUPERSONIC JET. Appendix - A POTENTIAL FLOW MODEL FOR THE FLOW IN THE VICINITY OF A BLUFF BASE. A. H. Craven. Coll. of Aeronautics, Cranfield, Rep. 129, Mar., 1960. 26 pp. Experimental and theoretical investigation into the effect of supersonic jets upon the base pressure of a bluff cylinder in a uniform subsonic flow. Jet stagnation pressures giving slight under-expansion of the jet cause an increase in the base pressure, but for larger jet stagnation pressures the base pressure is again reduced. A simple theory, based on a momentum integral, shows the dependence of the base drag upon the jet and free stream speeds and upon the dimensions of the jet and base.

Jet Flaps & Wings

A LIFTING LINE THEORY OF THE JET FLAPPED WING. Y. A. Yoler. Boeing Sci. Res. Lab. FSL Rep. 24, D1-82-0042, Jan., 1960. 30 pp. 14 refs. Analysis of performance characteristics of thin wings with jet flaps emerging at their trailing edges in terms of a pair of bound substitution vortices, located at the one-quarter and three-quarter chord points, and the associated system of shed vorticity. The existence of the jet at the trailing edge and/or flow separation is assumed to nullify the suction force at the trailing edge and the strength of the bound vortices is determined by using the thrust hypothesis. The theory developed on this basis is found to be in good agreement with experimental results in predicting the dependence of the aerodynamic characteristics on the thrust coefficient, angles of attack, and aspect ratio.

Stability & Control

STUDY OF THE AERODYNAMIC FORCES AND MOMENTS ON BODIES OF REVOLUTION IN COMBINED PITCHING AND YAWING MOTIONS. Murray Tobak and H. C. Lessing. US, NASA TN D-316,

May, 1960. 24 pp. OTS, $0.75. Discussion of significant errors in the accepted practice of writing the aerodynamic forces and moments that act on a body of revolution during pitching and yawing motion. A more correct formulation is presented which shows that, even with linear aerodynamic coefficients, the differential equations governing the motion are fundamentally nonlinear. This permits an explanation of certain types of motion which have been observed experimentally and which have been explainable previously only with the assumption of nonlinear aerodynamic characteristics.

NEKOTORYE VOPROSY AERODINAMIKI SAMOLETA S OTKLONENNOI STRUEI GAZOV REAKTIVNOGO DVIGATELIA. G. I. Andrenko. MVO SSSR VUZ Izv. Av. Tekh., No. 2, 1960, pp. 3-13. In Russian. Study of certain problems concerning the interaction between the aricraft and the deflected stream of gas from the jet power plant. The variation of aerodynamic characteristics of the aircraft in subsonic flight regimes at different deflection angles of the flow and ratios of deflected stream and incident flow velocities is studied. Two models were used: (a) with the power plant at the rear of the fuselage and (b) on the wing. Included is a detailed description of the installation and test equipment used, as well as presentation of experimental results.

Wings & Airfoils

THE PRESSURE DISTRIBUTION ON TWO-DIMENSIONAL WINGS NEAR THE GROUND. Appendix - THE VELOCITY FIELD OF A SOURCE DISTRIBUTION ON TWO PARALLEL LINES. J. A. Bagley. Gt. Brit., RAE Rep. Aero. 2625, Feb., 1960. 40 pp. 18 refs. Development of a method based on Tani's approach, but using an extended source distribution to represent the airfoil and its image, instead of the two doublets used by Tani. A distribution of vortices on two parallel lines is used to represent the airfoil at incidence and its image. Comparison with the exact potential flow solution of Tomotika and a series of experimental measurements on a 10% thick RAE 101 airfoil at distances between 0.5 chord and 0.23 chord from the ground verifies the method, provided allowance is made for the boundary layers on the airfoil and on the ground board. These comparisons suggest that the appropriate distance to use when calculating the pressure on the airfoil at incidence above the ground is the height of the mid-chord point.

SOME CALCULATIONS OF THE LOAD DISTRIBUTION ON FLAT SWEPT-BACK WINGS AT MACH ONE. C. R. Taylor. Gt. Brit., RAE TN Aero. 2664, Dec., 1959. 39 pp. 11 refs. Presentation of calculated results to show the effect of varying wing aspect ratio, tip shape, and taper on pressure distributions. For one wing, the effect of a fuselage has been calculated, and results are also given at the free-stream Mach number at which the wing trailing edges become sonic. The spanwise variation of local drag and leading edge thrust force coefficients are discussed in detail.

FLIGHT TESTS TO INVESTIGATE THE DYNAMIC LATERAL STABILITY CHARACTERISTICS OF A 45° DELTA AT THREE ASPECT RATIOS. J. E. Nethaway and J. Clark. Gt. Brit., RAE TN Aero. 2671, Feb., 1960. 27 pp. Presentation of flight test results for the Boulton-Paul IIIA aircraft with aspect ratios of 3.8, 3.0, and 2.3. They showed that the changes in damping, period, and phase angle were not large when the aspect ratio was varied, but the roll to yaw ratio increased considerably as aspect ratio was reduced. The comparison between characteristics measured in flight and those estimated is generally fair. Agreement is closest over the range of lift coefficients 0.28 to 0.45.

LINEAR SUPERSONIC FLOW PART COMBINATIONS OF A CYLINDRICAL BODY AND TRIANGULAR WINGS. Ferdinand Peischl and H. J. Stetter. Munich Tech. Hochsch. Math. Inst. TN 11 (AFOSR TN 59-1160), Nov. 24, 1959. 28 pp. 13 refs. Calculation of the normalized pressure distribution for wing-body combinations consisting of a cylindrical body and plane delta wings with supersonic leading edges. Linearized supersonic theory is used without further approximations. The pressure distribution is shown in several graphical representations and a discussion of the results is given.

FORCES ET MOMENTS NON LINEAIRES INDUITS PAR UNE AILE AVANT SUR UNE AILE ARRIERE ET LE FUSELAGE, DANS UNE CONFIGURATION ELANCEE. A. von Baranoff. France, ONERA NT 58, 1960. 23 pp. In French. Presentation of a synthesis of theoretical results obtained on the effects of interaction due to the turbulence produced by a fin located over the forward section and acting upon the rear section of a slender body. Details of numerical application are given, and the method of the slender body theory is used. It is assumed that the aerodynamic properties of the forward section of the body, in particular, the intensity of the vortex sheet immediately downstream of the trailing edge are known. The linearized supersonic theory is used to take the Mach number effect into account. Also included are numerical results for the induced lift in symmetrical flow and for the induced lift, lateral force, and rolling moment in slip flow.

AEROELASTICITY

AEROELASTIC CRITERION FOR LEADING EDGE STIFFNESS. M. J. Wooldridge. Aircraft Eng., July, 1960, pp. 192-194. Presentation of a composite chart to facilitate the rapid determination of a critical divergence stiffness for a straight or swept leading edge of a lifting surface. The aeroelastic criterion is intended for use in initial design work. To accommodate the effects of kinetic heating, the material temperature is taken as identical to that of the boundary layer adjacent to it. From the present chart it is possible to establish the critical room-temperature stiffness such that divergence of the leading edge tip will not occur below the corresponding Mach number for varying altitude and structure material.

ON THE RESPONSE OF A TRANSPORT AIRPLANE TO SIDE GUST. Hirosi Arai and Goro Beppu. Japan Soc. Aero. & Space Sci. J., May, 1960, pp. 1-6. In Japanese, with summary in English. Presentation of analytical results for airplanes having different values of lateral and directional stability to determine Dutch-roll and spiral stability characteristics, transfer functions of rolling and yawing response to a side gust, and power spectral densities and root mean square values of rolling and yawing in the atmospheric turbulence. Analog computer calculations of gust response are also made.

FORCES ET MOMENTS AGISSANT SUR UNE VOILURE VIBRANT EN AIR CALME. P. Salaün. La Recherche Aéronautique, Jan.-Feb., 1960, pp. 49-54. In French. Calculation of aerodynamic forces and moments acting upon wings vibrating in calm air, under the conditions of potential flow. The problem is linearized and then solved for the two-dimensional case. It is found that the forces and moments have the same value as those of the Küssner formula where the velocity at infinity upstream is nil.

AIRPLANES

Control Systems, Automatic Pilots

MULTICONDITION TERMINAL CONTROL SYSTEMS FOR AIRCRAFT. Appendix I - GENERAL SOLUTION TO A SET OF LINEAR DIFFERENTIAL EQUATIONS. Appendix II - REQUIREMENTS FOR THE FORCING INPUT. R. V. Morris and C. W. Steeg, Jr. J. Aerospace Sci., Sept., 1960, pp. 703-711. USAF-sponsored presentation of a method for synthesizing a type of control system applicable to automatic landing of aircraft. The closed-loop control system is designed to cause the response of a controlled member to meet several independently specified conditions at a particular instant of time. The desired values of altitude and altitude rate at touchdown typify such conditions. Because the system operates to shape the response at one time only, it is suitable for use with controlled members that have oscillatory or divergent responses to forcing inputs.

FUELS & LUBRICANTS

THE CHEMISTRY OF PROPELLANTS: A MEETING ORGANISED BY THE AGARD COMBUSTION AND PROPULSION PANEL, PARIS, FRANCE, JUNE 8-12, 1959. Editors: S. S. Penner and J. Ducarme. London, New York, Paris, Pergamon Press, 1960. 660 pp. 855 refs. $10. 70s. Contents: Participants in Discussions and Their Affiliation. Propellant Sources and Costs: Sources, Availability and Estimated Costs of Propellants, S. H. Dole and M. A. Margolis. Liquid Propellants: High-Temperature Thermodynamics and Theoretical Performance Evaluation of Rocket Propellants, R. J. Thompson. Liquid Propellants for Rockets, D. L. Armstrong. An Experimental Evaluation of Rocket Propellant Data, S. Greenfield. Discussions. Solid Propellants: Preparation and Properties of Double-Base Propellants, R. Steinberger. Préparation et Propriétés des Propergols - Propergols Solides Composites, P. Tavernier and J. Boisson. Methods of Burning Rate Control in Solid Propellants, G. H. S. Young. Propellants for Air-Breathing Engines: Combustibles pour Statoréacteur - Propriétés et Préparation, M. Barrère and G. Français. Performance Evaluation of Ramjet Propellants, E. Perchonok. Selected Basic Studies: Physico-Chemical Reactions During Nozzle Flow, J. F. Morris. On Deposits in Jet Engines, R. Breitwieser. Discussions. High-Energy Propellants and Basic Propulsion Problems: The Merits of Utilizing High-Energy Propellants, W. G. Parker and G. Ruston. Discussions. Round-Table Discussion on Basic Propulsion Problems. Comments to the Round-Table Discussions.

ALKALI METALS AS PROPELLANTS. Appendix I - SPECIFIC IMPULSE CALCULATIONS FOR TWO-PHASE SYSTEMS. Appendix II - TABLES OF THERMODYNAMIC DATA FOR GASEOUS LITHIUM AND SODIUM FLUORIDE, CHLORIDE, OXIDE, AND HYDROXIDE MONOMERS AND DIMERS. Alfred Büchler and Joan Berkowitz. USAF MDC TR 59-40, Nov., 1959. 91 pp. Presentation of data, calculations, and technical information to aid in the evaluation of alkali metals as propellants. The available thermodynamic data for gaseous LiF, NaF, LiCl, NaCl, Li_2O, LiOH, NaOH, and their dimers, are critically discussed and tables of thermodynamic functions based on these data are given. There appears to be no advantage in the use of alkali metal solutions or dispersions as propellants. The characteristics of liquid alkali metals, their solutions and dispersions, as well as the handling of the liquid metals, are comprehensively studied. Calculated specific impulses range from 97 sec. for sodium-water systems to 290 sec. for lithium-fluorine systems (stoichiometric mixtures).

RELATION ENTRE LA STRUCTURE CHIMIQUE ET LA REACTIVITE DES COMBUSTIBLES POUR FUSEES A L'ACIDE AZOTIQUE; CONSTANTES PHYSIQUES DES COMBUSTIBLES. Jacques Françon. France, Min. de l'Air NT 89, 1960. 47 pp. SDIT, 2 Av. Porte-d'Issy, Paris 15, NF 6.15. In French. Study of the relationship between the chemical structure of rocket propellants and their reaction to HNO_3 48 Be. The method used is described in detail. The velocity of combustion of several liquid propellants is studied and a number of their constants are determined.

MATERIALS

High Temperature

DETERMINATION OF FACTORS GOVERNING SELECTION AND APPLICATION OF MATERIALS FOR ABLATION COOLING OF HYPERVELOCITY VEHICLES. J. H. Bonin, Ch. F. Price, and Henry Halle. USAF WADC TR 59-87, Pt. III, Feb., 1960. 151 pp. Presentation of test results for 52 samples of different nonmetallic materials exposed to a high-temperature plasma discharge produced in an air-stabilized electric arc. The

sample shape, test conditions and procedure, and the material behavior are discussed.

Metals & Alloys

RAMBERG-OSGOOD AND HILL PARAMETERS OF AIRCRAFT STRUCTURAL MATERIALS AT ELEVATED TEMPERATURES. R. M. Rivello. U. Md. Dept. Aero. Eng. Aero. Rep. 60-1, Mar., 1960. 32 pp. 23 refs. Presentation of two analytic expressions for stress-strain curves of stresses slighthly beyond the yield stress. Curves are given for the variation of these parameters with temperature for the more commonly used alloys of aluminum, magnesium, steel, inconel, and titanium. The data which are for short time exposure to elevated temperature (1/2 hour exposure before testing at a strain rate of approximately 0.002 per min.) were computed from elevated temperature stress-strain curves which have been previously published.

MISSILE, ROCKET, & SPACE TECHNOLOGY

INVESTIGATION OF THE NATURAL FREQUENCIES OF FLUIDS IN SPHERICAL AND CYLINDRICAL TANKS. J. L. McCarty and D. G. Stephens. US, NASA TN D-252, May, 1960. 20 pp. 14 refs. OTS, $0.50. Investigation of the natural frequencies and mode shapes of fluids contained in representative missile fuel-tank configurations. The natural-frequency data obtained from fluids in spherical and cylindrical tanks of different sizes, fullness, and orientation with respect to the direction of oscillation are presented in nondimensional form and are compared with available analytical results.

Ballistics, Re-Entry

DYNAMIQUE DU VOL - LA RESONANCE DES MISSILES TOURNANTS. Appendix - ETUDE MATHEMATIQUE DU MOUVEMENT PENDANT LA TRAVERSEE DE L'ATMOSPHERE. M. Bismut. La Recherche Aéronautique, Jan.-Feb., 1960, pp. 3-11. In French. Theoretical investigation of the mechanism of spin resonance in missiles during flight at constant altitude or along a constant slope. Results of an analog calculation are used to complement the study. The random character of the phenomenon due to the asymmetric structure of the missile is emphasized and methods of alleviating it are indicated.

NORMAL LUNAR IMPACT ANALYSIS. Anthony Liu. J. Astron. Sci., Summer, 1960, pp. 35-38. Analysis based on the assumption of a normal impact, showing that higher energy orbits strike closer to the center of the lunar disc than lower energy orbits. In addition, areas of the moon to be reached by elliptical, hyperbolic, or parabolic orbits for normal impacts depending upon the initial conditions near the earth are designated.

FUEL REQUIREMENTS FOR INTER-ORBITAL TRANSFER OF A ROCKET. R. N. A. Plimmer. (10th Internatl. Astron. Congr., London, Sept., 1959.) Gt. Brit., RAE TN G.W. 539, Mar., 1960. 37 pp. Study concerning coplanar orbit-to-orbit minimum fuel transfers. Optimal transfers between circular orbits (Hohmann transfers), between an elliptical orbit and a circular orbit, between elliptical orbits having a common direction of major axes and the same eccentricity, and, finally, between elliptical orbits which are identical except for the direction of their major axes are all discussed in detail, considering the field of all possible initial and final terminal orbits. A comparison of the fuel requirements is made between these optimal transfers and certain other modes of nonoptimal transfer.

EFFECT ON A ROCKET OF THE OBLATENESS OF A PLANET. W. A. Allen. ARS J., July, 1960, pp. 623-627. 11 refs. Application of an approximation technique to solve the problem of a rocket moving radially away from a planet. The planet is characterized by a gravitational potential that includes effects of its oblateness. A first integral, relating velocity and distance, is obtained immediately; a second integral, relating time and distance, is obtained by a quadrature. This second relation is expressible approximately in terms of elliptic integrals reducible to elementary types that have been tabulated. Inclusive of second-order terms the solution is carried through completely, and the inclusion of fourth-order terms is indicated. The approximate results are compared with the exact values obtained by numerical integration. Evaluation of a numerical example indicates that the solution inclusive of second-order terms is equivalent to the exact solution, and that the fourth- and other higher-order terms are negligible for the case of a rocket leaving earth with an acceleration about ten times that due to gravity.

ROCKET BOOST TRAJECTORIES FOR MAXIMUM BURNOUT VELOCITY. L. J. Kulakowski and R. T. Stancil. ARS J., July, 1960, pp. 612-618. Analysis considering the definition of optimal trajectory programs which allow a given rocket boost vehicle to launch its payload with maximum velocity, for prescribed burnout values of the path angle and altitude. Methods of the calculus of variations are employed to achieve the desired solutions. The equations of motion consider a spherical nonrotating earth model and include the effects of aerodynamic forces. Inequality constraints suitable for satisfying certain practical vehicle design and physiological limits are introduced. An optimal coasting period of initially unspecified duration may be included in the trajectory to provide increased burnout altitude.

Guidance, Control, Stability

ATTITUDE DRIFT OF SPACE VEHICLES. W. T. Thomson and G. S. Reiter. J. Astron. Sci., Summer, 1960, pp. 29-34. Study of the Explorer I satellite showing that the attitude of a body of revolution spinning in the absence of external forces is not a constant when energy dissipation takes place. Elastic vibration, induced by gyroscopic

action, results in a dissipation of energy and a change in the precession cone angle θ. The effects of energy dissipation on the spinning body are examined, and the time required for a body of given configuration to undergo a specified change in attitude is evaluated.

INERTIAL METHOD OF VELOCITY MEASUREMENT. V. N. Drozdovich. (MVO SSSR VUZ Izv. Priborostr., No. 3, 1959, pp. 29, 30.) ARS J. Suppl., July, 1960, pp. 668-672. Translation. Analysis of the systematic errors due to Coriolis and centripetal accelerations, and evaluation of these errors when velocity is measured over prolonged intervals of time. The role of Coulomb friction is explained and an estimate is given of the static error due to this friction. It is concluded that a correction system must include additional devices that take into account the parameters of the course and the position of the object on the course.

THE LIBRATION OF A SATELLITE. V. V. Beletskiy. (Iskusstv. Sputniki Zemli, No. 3, 1959, pp. 13-31.) US, NASA TT F-10, May, 1960. 34 pp. 16 refs. OTS, $1.00. Translation. Application of the methods of Liapunov-Chetayev to find conditions for the existence and stability of the relative equilibrium of a material body in orbit in a Newtonian central-force field and to consider the oscillations of the body around the position of relative equilibrium. It is noted that in the actual libration of an artificial satellite, a number of small perturbing factors have an influence: the moments of the aerodynamic forces, perturbing moments caused by deviations of the attractive field of the earth from a central-force field, regression of the orbit as a result of the compression of the earth and aerodynamic resistance, and moments of the electromagnetic fields. Studies show that if the basic conditions of stability are satisfied, as well as certain other natural conditions, libration in the presence of the perturbations will differ only slightly from unperturbed libration.

Spacecraft

DEPENDENCE OF SECULAR VARIATIONS OF ORBIT ELEMENTS ON AIR RESISTANCE. P. E. El'yasberg. (Iskusstv. Sputniki Zemli, No. 3, 1959, pp. 54-60.) ARS J. Suppl., July, 1960, pp. 672-675. Translation. Extension of an idea proposed by Yatsunskii concerning the series expansion of the secular variations in the orbital elements in terms of Bessel functions of an imaginary argument. This technique produces simple descriptive formulas which can be used to solve a number of problems, such as determining the dependence of secular variations in orbit elements on the magnitude of these elements and evaluating the accuracy of air density determinations on the basis of measurements of the secular variations in the orbit elements. Analytical expressions are obtained for changes caused by air resistance in the latus rectum of the orbit, the eccentricity, the major semiaxis, the period of revolution, and the distance from the perigee to the center of the earth.

ERROR ANALYSIS OF SATELLITE ORBITS IN THE PRESENCE OF DRAG. F. V. Pohle. J. Astron. Sci., Summer, 1960, pp. 40-44. USAF-supported application of first-order perturbation solutions of satellite orbits to determine the error in the altitude, at the end of a half revolution, due separately to (1) errors in the initial altitude, (2) initial horizontal speed, (3) perturbation parameter, and (4) decay parameter in the exponential density function. The error in the speed, at the end of a half revolution, is also determined as a function of the same parameters. The present analysis is restricted to the case of a horizontal velocity at the initial position. In the absence of drag, information can be obtained easily on the effect of initial nonzero vertical speed upon the orbit.

PERTURBATIONS OF ORBITS OF ARTIFICIAL SATELLITES DUE TO AIR RESISTANCE. Yu. V. Batrakov and V. F. Proskurin. (Iskusstv. Sputniki Zemli, No. 3, 1959, pp. 39-46.) ARS J. Suppl., July, 1960, pp. 700-704. Translation. Development of a general form of first-order perturbations in the elements of the elliptical orbit of a satellite caused only by atmospheric resistance. It is assumed that the earth's atmosphere has a strictly spherical density distribution and that the earth's attraction can be substituted by the attraction of a mass point located at its center of mass and having the same mass as the earth. Short-period perturbations, the periods of which do not exceed the period of one revolution of the satellite, are obtained together with the secular perturbations. A numerical example showing the comparative value of first-order perturbations caused by the resistance of the air is also given.

THE CAPTURE PROBLEM IN THE THREE-BODY RESTRICTED ORBITAL PROBLEM. V. A. Yegorov. (Iskusstv. Sputniki Zemli, No. 3, 1959.) US, NASA TT F-9, Apr., 1960. 16 pp. OTS, $0.50. Translation. Presentation of the proof for a theorem connected with the three-body capture problem. It is shown that in the case where one of the attractive masses is sufficiently small with respect to the other, a point of zero mass starting infinitely far away cannot remain forever in the sphere of attraction of the smaller mass - i.e., become a satellite.

GENERAL RESEARCH IN FLIGHT SCIENCES - FLUID MECHANICS. IX - CHARGE AND MAGNETIC FIELD INTERACTION WITH SATELLITES. D. B. Beard and F. S. Johnson. Lockheed Aircraft Missiles & Space Div., vol. I, Pt. II, TR LMSD-288139, Jan., 1959-Jan., 1960. 19 pp. Analysis of the interaction of a satellite with the magnetic field of the earth and the ionized medium through which it is moving. Due to the differing incident velocities of ions and electrons and, therefore, differing incident flux intensities, a negative

potential will be induced on the satellite, but this potential is smaller than has been believed. Satellite motion across the magnetic lines of the earth will induce a voltage on the satellite of as much as 0.2 volts/meter of satellite size, and this may affect the interpretation of measurements of satellite potential. The magnetic drag resulting from the induced currents is proportional to the cube of the satellite dimensions and may exceed the mass drag for satellites larger than 50 m. in diam.; this can only occur above 1,200-km. altitude where the charge density exceeds the neutral density. Thus, the magnetically induced current is an insignificant cause of drag.

PHYSICS

RELAXATION PROCESSES AND REACTION RATES BEHIND SHOCK FRONTS IN AIR AND COMPONENT GASES. K. Wray, J. D. Teare, B. Kivel, and P. Hammerling. Avco Everett Res. Lab. RR 83 (AFBMD TR 60-26), Dec., 1959. 30 pp. 25 refs. USAF-Army-supported description of three classes of experiments: (1) absorption of ultraviolet radiation, (2) emission of optical radiation, and (3) microwave absorption and reflection. The ultraviolet absorption experiments measure the density of molecules in the ground state and determine the thermally significant changes occurring in the nonequilibrium region. The emission experiment gives directly the magnitude of nonequilibrium radiation at the front of a normal shock. The microwave measurements are used in conjunction with d.c. conductivity measurements to determine the rate and degree of ionization. The current values used to correlate the experimental data for chemical and electronic rate constants are quoted.

POWER PLANTS

Jet & Turbine

ON ENGINING THE JET FLAP. Appendix I, II - THE APPROXIMATE ASSESSMENT OF JET FLAP LIFTING PERFORMANCE. Appendix III - SOME ENGINE DATA AT THE DESIGN POINT. Appendix IV - SCALING THE ENGINE PERFORMANCE. I. M. Davidson and N. G. Robertson. Gt. Brit., NGTE Rep. R.242, Apr., 1960. 24 pp. Study of the application of ducted fan engines in which the by-pass air alone is used to feed the jet flap. Because the working fluid is cold, at low pressure, and free from the contamination by fuel, lightweight nonmetallic ducting will be possible. In addition, there appears to be no serious aircraft stability or engine matching problem when one of a battery of four engines fails.

FULL-SCALE WIND-TUNNEL TESTS OF A SWEPT-WING AIRPLANE WITH A CASCADE-TYPE THRUST REVERSER. M. W. Kelly, R. K. Greif, and W. H. Tolhurst, Jr. US, NASA TN D-311, Apr., 1960. 31 pp. OTS, $1.00. Presentation of the results of a full-scale wind-tunnel investigation of an F-100F airplane equipped with a cascade-type thrust reverser. The purpose of this investigation was to develop a thrust reverser satisfactory for use during the landing approach. Longitudinal and lateral-directional stability and control data are presented for a number of reverser configurations. A reverser configuration was achieved which had only mild effects on the stability and control of the airplane, and which is believed to be satisfactory for flight research work.

Rocket

A ONE-DIMENSIONAL THEORY OF LIQUID-FUEL ROCKET COMBUSTION. III - THE EFFECT OF NON-UNIFORM DROPLET RADII, INJECTION VELOCITIES AND PHYSICAL PROPERTIES. J. Adler. Gt. Brit., ARC CP 469, 1960. 15 pp. BIS, New York, $0.36. Extension of the one-dimensional liquid-fuel rocket combustion theory of Spalding to apply to models consisting of two different droplet groups. In one model, droplet radii and injection velocities are varied, and in the other the particle densities and mass transfer numbers are nonuniform. Solutions are obtained for the variation of droplet radius, velocity, and gas velocity with distance from the injection end.

RESEARCH, RESEARCH FACILITIES

A STUDY OF METHODS FOR SIMULATING THE ATMOSPHERE ENTRY OF VEHICLES WITH SMALL-SCALE MODELS. Appendix A, B - TURBULENT HEATING RATES. Appendix C - SIMULATION OF HIGHLY ELLIPTIC, PARABOLIC, AND HYPERBOLIC ENTRIES. B. L. Swenson. US, NASA TN D-90, Apr., 1960. 51 pp. OTS, $1.50. Presentation of an analysis of the motion and aerodynamic heating of both glide and ballistic vehicles during atmosphere entry. Approximate trajectories are developed and it is shown that a generalized heating-rate history is possible for different types of vehicles and trajectories. Simulation of the effects of heating on various heat shielding designs is considered. Similarity relations for the investigation of full-scale vehicles by testing small-scale models are developed.

Wind Tunnels

AN INVESTIGATION OF THE MODEL BLOCKAGE FOR WIND TUNNELS AT MACH NUMBERS 1.5 TO 19.5. C. J. Schueler. USAF AEDC TN 59-165, Feb., 1960. 20 pp. Study of test section flow blockage characteristics conducted in the 12- x 12-in. supersonic wind tunnel to determine whether a method of predicting the maximum size model which will permit the establishment of supersonic flow, based on the model frontal area and bow shock-wave strength, is applicable over a wide range of Mach numbers. The tests were conducted over the Mach number range from 1.5 to 5 using test models consisting of 15°, 20°, and 28° half-angle cones, cone-cylinder combinations, and a series of discs. The inadequacy of the one-dimensional, normal shock theory for predicting allowable model sizes was reconfirmed in these tests. Furthermore, a correlation based on shock

wave strength and model frontal area was found to be suitable only over a limited range of Mach numbers.

ROTATING WING AIRCRAFT, HELICOPTERS

TABLES AND CHARTS FOR ESTIMATING STALL EFFECTS ON LIFTING-ROTOR CHARACTERISTICS. Alfred Gessow and R. J. Tapscott. US, NASA TN D-243, May, 1960. 45 pp. OTS, $1.25. Presentation of data calculated for a rotor having rectangular blades with -8° of twist with the use of a representative set of airfoil section lift and drag characteristics covering a 180° angle-of-attack range. The characteristics include rotor blade motion, rotor thrust, total power, profile-drag power, and orientation of the rotor resultant force vector. The charts and tables are useful in estimating the effects of stall on rotor blade motion, rotor performance, stability derivatives, and load factors.

RESPONSE OF ROTOR LIFT TO AN INCREASE IN COLLECTIVE PITCH IN THE CASE OF DESCENDING FLIGHT, THE REGIME OF THE ROTOR BEING NEAR AUTOROTATION. Jean Rebont, Jean Soulez-Larivière, and Jacques Valensi. (Acad. Sci. Comptes Rendus, No. 9, Sept. 1, 1958, pp. 738-741.) US, NASA TT F-18, Apr., 1960. 5 pp. OTS, $0.50. Translation. Presentation of a method to determine the induced velocity and the overall lift of the rotor as a function of the collective pitch for all values of the advance per turn. The nature of the lift response is shown to be essentially a function of the rate of pitch change.

THE AVOIDANCE OF GROUND RESONANCE; EXACT STABILITY CRITERIA FOR HELICOPTERS ON ISOTROPIC SUPPORTS. I, II. H. L. Price. Aircraft Eng., June; July, 1960, pp. 156-160; 195-200. Study of the manner in which the ground resonance properties of a helicopter depend on the fuselage damping, blade damping, drag hinge offset, interblade stiffness, blade mass, and angular velocity of the rotor as specified by the parameters λ_f, λ_β, Λ_1, Λ_2, Λ_3, and Ω, respectively. A direct method of drawing stability boundaries in the (Ω, λ_β) plane is developed, and the geometry of these boundaries as the remaining parameters vary is studied theoretically at length. Arising out of the geometry, the validity of Coleman's criterion for stability is examined, and it is shown that the requirement that the product of the damping factors $\lambda_f \lambda_\beta$ should have a certain minimum value is not itself sufficient to ensure stability for all angular velocities of the rotor. The condition can be made sufficient by a proper and unique choice of the individual values of λ_f and λ_β, and these values are found in terms of Λ_1, Λ_2, Λ_3. All other cases of stability require a larger value of the product $\lambda_f \lambda_\beta$.

AN EXPERIMENTAL INVESTIGATION OF STALL FLUTTER ON A MODEL HELICOPTER ROTOR IN FORWARD FLIGHT. N. D. Ham. MIT ASRL TR 86-1, Mar., 1960. 43 pp. Navy-supported study of stall flutter which is found to occur in all forward flight cases involving appreciable blade stall. Stall flutter consisted almost entirely of blade motion in the torsional mode, and the amplitude is found to be dependent on such parameters as blade chordwise c.g. position, blade torsional damping, blade torsional frequency, and the degree of stall occurring over the rotor disc. The results indicate that more information is required regarding the torsional aerodynamic damping of stalled rotating blades.

STRUCTURES

PRACTICAL ASPECTS OF STRUCTURAL ANALYSIS. B. Langefors. ZFW, June, 1960, pp. 161-168; Discussion - ON THE MATRIX THEORY OF STRUCTURES: CONCLUSION AND DISCUSSION, J. H. Argyris and S. Kelsey, pp. 169-172. 14 refs. Review of procedures for the practical application of matrix methods to structural design. Routine methods and computer programs for establishing the structure matrices for a given structure and for manipulation of these matrices in an automatic way are described. The use of electronic computers and "autocoding" systems has made a high degree of automatization of these problems possible.

MINIMUM WEIGHT ANALYSIS BASED ON STRUCTURAL RELIABILITY. H. H. Hilton and Morris Feigen. (3rd Symposium High-Speed Aerodynamics & Struc., San Diego, Mar. 27, 1958.) J. Aerospace Sci., Sept., 1960, pp. 641-652. 12 refs. Analysis in which the concepts of minimum weight analysis and structural reliability are combined to determine how to assign probabilities of failure to the various structural components such that the total structural weight is a minimum and the probability of failure of the entire structure is equal to a preassigned value. The solution is expressed in terms of general loads of known probability of occurrence and normal distributions of failure stresses, which are assumed to be known from prior tests on given types of structures, loads, and materials. It is shown that for a given total structural probability of failure of a multicomponent structure, as any component becomes heavier it should be assigned a higher probability of failure in order to achieve minimum weight for the entire structure. The relationship of the margin of safety to probability of failure is discussed.

Connections

RANGE OF INTERFACE THERMAL CONDUCTANCE FOR AIRCRAFT JOINTS. M. E. Barzelay. US, NASA TN D-426, May, 1960. 63 pp. OTS, $1.75. Presentation of test results obtained under simulated aerodynamic heating conditions with more than 100 aluminum-alloy and high-temperature-alloy structural-joint specimens consisting of a stringer joined to a skin surface. Interface thermal conductance was determined from transient temperature records. Most of the specimens were geometrically identical and of the same alu-

minum alloy in order to take into account the effect of manufacturing variability and of many different types of fastenings; the heat input was nearly constant during any given test; mean interface temperatures as high as 600°F. were achieved during the transient heating; and most of the tests were conducted during a period of less than one minute.

Cylinders & Shells

AN IMPROVED FIRST-APPROXIMATION THEORY FOR THIN SHELLS. Appendix A - SMALL RIGID-BODY MOTIONS. Appendix B - EQUATIONS OF THE THEORY FOR A CIRCULAR CYLINDER. J. L. Sanders, Jr. US, NASA TR R-24, 1959. 11 pp. Supt. of Doc., Wash., $0.30. Derivation of an improved form of Love's first-approximation theory for thin shells. In contrast to the results of Love's theory, all strains in the proposed theory vanish for rigid-body motions. Expressions for the stress resultants and couples which satisfy the homogeneous equilibrium equations are given in terms of three stress functions.

SANDWICH CYLINDERS. II - UNIFORMITY OF THE MECHANICAL PROPERTIES OF THE CORE IN CYLINDRICAL SANDWICH CONSTRUCTION. M. I. Kazimi. Aerospace Engrg., Sept., 1960, pp. 34-45. Experimental investigation to verify the anticlastic nature of sandwich cylinder cores. Limited tests under axial compression and uniform external lateral pressure were conducted. Two types of sandwich cylinders of the same weight, geometry, and facing characteristics (one using normally expanded and the other overexpanded paper core) and a solid shell were tested. Tests results indicate that the overexpanded core is superior to normal-expanded one. This was expected since the overexpanded core will have a more uniform shear modulus over the total cylinder than the normal-expanded core. It is concluded, however, that a specially designed radial core capable of assuming a cylindrical shape will yield even better results.

BENDING AND COMPRESSION TESTS OF PRESSURIZED RING-STIFFENED CYLINDERS. M. B. Dow and J. P. Peterson. US, NASA TN D-360, Apr., 1960. 27 pp. OTS, $0.75. Discussion of the results of tests on pressurized ring-stiffened cylinders subjected to compression and bending. The results obtained at high values of internal pressure differ from those obtained by previous investigators in that the theoretical small-deflection compressive buckling coefficient of 0.6 was nearly achieved in each test. Small amounts of internal pressure had a greater stabilizing effect in the bending tests than in the compression tests.

CREEP AND PLASTIC DEFORMATION IN CYLINDRICAL SHELLS. A. M. Freudenthal and M. P. Bieniek. USAF WADC TR 59-399, Mar., 1960. 16 pp. Analysis of creep deformation and bending moments in the vicinity of a freely supported or fixed end of a long, cylindrical shell. Solutions are given under conditions of stationary (second stage) creep, using an approximate method based on extremum principles of dissipative media which are valid for an assumed uniaxial and nonlinear creep law. The results of tests of steel cylinders under internal pressure, producing large plastic deformation, are given, illustrating the relation between problems of nonlinear creep and plastic deformation.

Elasticity & Plasticity

SOME EXPERIMENTS CONCERNING SUBSEQUENT YIELD SURFACES IN PLASTICITY. H. G. McComb, Jr. US, NASA TN D-396, June, 1960. 33 pp. OTS, $1.00. Discussion of some combined load tests made on seven thin-walled tube specimens of 2014-T4 aluminum alloy. The secondary yield surface is outlined in the normal-stress - shear-stress phase for an initial loading in pure tension. The significant changes in the shape of the stress-strain curves obtained from the tests of the thin-walled tube specimens are discussed.

THERMODYNAMIC FOUNDATIONS OF THE THEORY OF DEFORMATION. J. F. Besseling. (Durand Centennial Conf. on Aero. & Astron., Stanford, Cal., Aug. 5-8, 1959.) Stanford U. Dept. Aero. Eng. SUDAER 86 (AFOSR TN 59-871), Aug., 1959. 26 pp. Study considering the development of a continuum theory of deformation based on thermodynamic principles, the Galilean principle of relativity, and the concept of a natural reference state which at any instant is reproducible by a reversible process. The theory is restricted to small inelastic strains. Explicit relations in terms of material properties are presented for small deviations from the natural reference state. Attention in drawn to the inherent nonlinearity of the thermoelastic equations in dynamic problems.

Plates

BENDING OF ISOTROPIC THIN SQUARE PLATES BY CONCENTRATED EDGE COUPLES AND FORCES. R. S. Dhaliwal. Appl. Sci. Res., Sect. A, No. 5, 1960, pp. 297-318. 11 refs. Application of the complex variable method of Muskhelishvili to problems of bending for small deflections of thin, isotropic, homogeneous plates. The necessary conformal mapping function is found from the Schwarz-Christoffel formula or expansion of elliptic functions. A general solution is given for plates which can be mapped on a unit circle by polynomial type mapping functions. Three particular problems are worked out in detail: those of approximately square plates subjected, respectively, to two bending couples, to two twisting couples, both applied at the ends of a diagonal, and to four forces applied at the four corners. Numerical results are presented in the form of tables and graphs.

THE BUCKLING OF A THICK CIRCULAR PLATE USING A NON-LINEAR THEORY. Ch. B. Sensenig. NYU Inst. Math. Sci. Rep. IMM262 (AFOSR TN 60-41), Dec., 1959. 18 pp. Study of equilibrium stability of an isotropic circular cylinder when compressed along its curved lateral surface. The compression on the curved part of the boundary is assumed to be such that the generators of the cylinder remain vertical straight lines, but with no shear stress being developed; it is as though the cylinder were compressed by shrinking a very stiff greased ring down on it. The problem is treated by a nonlinear three-dimensional theory of elasticity of the type used by Green and Zerna, and is formulated using Lagrange coordinates and a matrix notation. The critical buckling pressures and the modes are given. They are the same as those furnished by the classical thin plate theory in the limit case of small thickness of the cylinder.

COMBINATIONS OF SHEAR, COMPRESSIVE THERMAL, AND COMPRESSIVE LOAD STRESSES FOR THE ONSET OF PERMANENT BUCKLES IN PLATES. G. W. Zender and J. B. Hall, Jr. US, NASA TN D-384, May, 1960. 26 pp. OTS, $0.75. Development of a semiempirical method for evaluating the onset of permanent buckling in plates. It is shown that the shear and compressive stresses required for the onset of permanent buckles may be approximated by a parabolic interaction curve. Thermal stresses are included by treating the compressive stress as being composed of a thermal component and a load component and employing the appropriate material properties at the elevated temperature. The results show that the compressive load stress which a plate can support at the onset of permanent buckling is reduced by thermal compressive stresses and by shear stresses. Results of the method are compared with experimental values obtained from tests of square tubes of 17-7 PH (Condition TH 1050) stainless steel.

PLATE DESIGN FOR MINIMUM WEIGHT. R. T. Shield. Quart. Appl. Math., July, 1960, pp. 131-144. 10 refs. Army-sponsored development of a method for the minimum weight design of transversely loaded plates other than circular plates. The basic equations are formulated and the four different types of solution are discussed. An inverse method is developed to obtain the minimum volume design for plates with built-in edge conditions. The method is used to obtain the design for an elliptical plate.

Plates with Holes

THE STRESSES AROUND REINFORCED ELLIPTICAL HOLES IN PLANE SHEET. W. H. Wittrick. Australia, ARL Rep. SM. 267, May, 1959. 45 pp. Development of solutions for a wide range of elliptical holes of various shapes, with various amounts of uniform reinforcement around the hole, and for various types of loading at infinity. In the case of a window opening in a pressurized fuselage, a stress concentration factor of 1.09, due to the pressure loads alone, can be achieved by using a uniform reinforcing member whose total weight is only about half that required for Mansfield's neutral hole, but with the same shape of ellipse - i.e., with axes in the ratio $\sqrt{2}$. A curve showing the minimum possible stress concentration factor for various shapes of ellipse is presented.

Sandwich Construction

SANDWICH CONSTRUCTION. I - THE STRENGTH OF FLAT SANDWICH PANELS. W. G. Heath. Aircraft Eng., July, 1960, pp. 186-191. Review and extension of existing theory to include panels with faces of unequal thicknesses and aeolotropic cores such as honeycomb. The various modes of failure are described, and comparisons are drawn between the equilibrium equations and those derived in the theory of solid plates. A very simple equation for the overall instability of a sandwich panel is obtained, based on the concept of "width reduction factors" which make allowance for core flexibility and unequal face thicknesses. Methods are described for presenting these reduction factors and other important parameters in the form of data sheets.

Thermal Stress

ON THE STEADY-STATE THERMOELASTIC PROBLEM FOR THE HALF-SPACE AND THE THICK PLATE. I. N. Sneddon and F. J. Lockett. Quart. Appl. Math., July, 1960, pp. 145-153. USAF-supported development of a general solution, corresponding to an arbitrary temperature field, in the form of double integrals and confirmation of Sternberg and McDowell's result that the stress field is plane and parallel to the boundary of the medium. The particular solution corresponding to axially symmetrical temperature fields is deduced and a solution is found for the problem in which the surface temperature is uniform over a circular region of exposure and is zero outside. The corresponding analysis of the steady-state displacements and stresses produced by arbitrary distributions of temperature on the surfaces of a thick plate is then given. It is shown that Sternberg and McDowell's result holds for a thick plate as well as for a semi-infinite solid. To illustrate the use of the method, the isochromatic surfaces within a thick plate are constructed for a special distribution of surface temperatures.

CREEP IN AIRCRAFT STRUCTURES. P. W. Kleeman. Australia, ARL S&M Rep. 269, Sept., 1959. 32 pp. 61 refs. Review of stress-strain relations, methods of analysis, and material data as they relate to creep buckling of columns, plates, and shells; redistribution of stress under creep conditions; and the estimation of total structural deformation. It is concluded that creep will be a design consideration in limited temperature ranges below 450°C., although its precise importance depends on the specific application. The magnitude of allowable creep strains has been suggested as being of the order 0.002 but there is need for a statement of the aerodynamic limitations on deformations if more precise limits are to be placed

on the permissible strains. In addition, the temperature at which creep buckling becomes an important design consideration in a specific application has yet to be defined. Empirical methods for predicting this are available but require further verification.

THERMODYNAMICS

A METHOD OF FORMING CONTINUOUS EMPIRICAL EQUATIONS FOR THE THERMODYNAMIC PROPERTIES OF AIR FROM AMBIENT TEMPERATURES TO 15,000°K, WITH APPLICATIONS. Martin Grabau. USAF AEDC TN 59-102, Aug., 1959. 41 pp. Presentation of a system for automatic data reduction for arc-driven, hotshot-type wind tunnels. Certain thermodynamic functions H ρ/p, S/R, and 1/Z (Z being the compressibility factor) for air, plotted at constant density as a function of the logarithm of the pressure, are found to exhibit basically similar graphical type-forms throughout the thermodynamic domain between 200°K. and 15,000°K. and the densities between 10^{-6} and 10^{2} relative atmosphere. This basic type-form is closely approximated by segments of straight lines connected by transition functions which are asymptotic at both ends. It is shown that the Fermi-Dirac and Bose-Einstein functions serve as kernels of such transition functions, respectively, when a point of inflection en route is or is not indicated. Any number of such transition functions can be superimposed by simple addition, thereby rendering it possible to write a continuous equation involving as many transitions as may be necessary.

Combustion

KINETICAL PARAMETERS IN PREMIXED LAMINAR FLAMES. A. Van Tiggelen, R. Corbeels, and H. Vandenabeele. U. Louvain Lab. Inorganic Chem. TN 2 (AFOSR TN 59-1149), Feb., 1960. 43 pp. 17 refs. Experimental and theoretical investigation of reaction kinetics in flames based on a simple chemical model for flame propagation which has been presented previously. The reaction orders of methane-oxygen and acetylene-oxygen mixtures are determined with respect to fuel and oxidant concentration in the flammable mixtures. The reaction orders are then related to the overall process of chain branching, since the proposed theory assumes the necessity for the chain carriers to undergo at least one branching reaction before they leave the flame front with the burned gases. In addition, some experimental results are obtained in the study of flame propagation for mixtures containing two different fuels (methane and hydrogen) in varying proportions and one single oxidant (oxygen).

Heat Transfer

CONVECTION DE LA CHALEUR EN REGIME LAMINAIRE DANS LE CAS D'UN GRADIENT DE PRESSION ET D'UNE TEMPERATURE DE PAROI QUELCONQUES, LE FLUIDE ETANT A PROPRIETES PHYSIQUES CONSTANTES. B. Le Fur. Internatl. J. Heat & Mass Transfer, June, 1960, pp. 68-80. In French. Study of the laminar boundary layer over a two-dimensional body, introducing an iterative procedure for the integration of momentum and energy equations in the form given by von Mises. The differential equations are solved in the first approximation, and covered are: the frictional stress at the wall, density of the heat flux at the wall and the thermal parietal friction factor, effective mean temperature and mean convection coefficient, and a comparison with the Lighthill method. The particular case of a dihedron with uniform temperature is also studied, including the local friction, local convection, and mean convection coefficients. The derived method determines the value of the density of the heat flux with a maximum error of 15%.

ONE-DIMENSIONAL ENERGY TRANSFER IN RADIANT MEDIA. R. Goulard and M. Goulard. Internatl. J. Heat & Mass Transfer, June, 1960, pp. 81-91. 17 refs. Army-supported extension of one-dimensional radiative energy transfer from their classical astrophysics form to include walls of arbitrary radiative properties. The concepts of emissivity and penetration length are examined. As an application, the case of steady infinite flat layer is considered with conduction and radiation present. It is found that the effect of the "long-range" process of radiation is to smooth out the temperature profiles and relieve the sharp temperature gradients at the cool wall. As a result, the application of the exact method yields a lower value of both components of the total heat flux (radiation plus convection) than calculated previously by assuming a temperature profile on the basis of conduction only. Such coupling of convective and radiative fluxes is governed by the magnitude of a nondimensional parameter, depending on the physical properties and the flow geometry of the problem.

VTOL & STOL

VLIIANIE GLUBINY RASPOLOZHENIIA VINTA V KOL'TSE NA AERODINAMICHESKIE KHARAKTERISTIKI SISTEMY DLIA REZHIMA RABOTY NA MESTE. V. I. Shaidakov. MVO SSSR VUZ Izv. Av. Tekh., No. 2, 1960, pp. 22-30. In Russian. Study of flying platforms equipped with ducted fan engines, covering the effect of the fan location on the aerodynamic characteristics of the system for the stationary operating regime. The case considered is that of a fan set deep in a duct with flared edges in the form of a half-circle of radius r_k. The theory of an ideal system is considered under the following assumptions: in the case of an ideal fluid and in the absence of frictional forces the flow propagates at infinity; losses due to aerodynamic blade friction are absent; induction losses due to the curling up of the flow behind the fan are negligibly small; and the velocities in any section of the flow are constant. The theoretical results are modified for the real system, and a comparison is made with available experimental data.

Selected Borides, Silicides and Carbides. A. D. Kiffer. *USAF WADD TR 60-52*, Apr., 1960. 24 pp.

O Mekhanicheskoi Prochnosti Keramicheskikh Materialov. V. G. Bravinskii. *AN SSSR Dokl.*, Mar. 1, 1960, pp. 82–84. 13 refs. In Russian. Experimental investigation of the mechanical properties of ceramic materials, showing the importance of surface inhomogeneity, as well as the role of internal porosity.

Ceramics Help Solve Rocket Problems. W. T. Monagle. *(SAE Natl. Aero. Meeting, New York, Apr. 5–8, 1960, Preprint 168B.) SAE J.*, June, 1960, pp. 54–62.

Corrosion & Protective Coatings

Relentless Bugaboo—Corrosion. J. P. Kushnerick. *Aircraft & Missiles*, July, 1960, pp. 48–50. Discusssion of the technique of applying chromate conversion coatings on aluminum parts for missile components. The properties of these coatings are presented.

Etude du Processus de Germination dans la Réaction de l'Oxygène sur le Cuivre aux Températures Elevées. Finn Gronlund. *France, Min. de l'Air NT 88*, 1960. 44 pp. 33 refs. SDIT, 2 Av. Porte-d'Issy, Paris 15, NF 7.50. In French. Description of investigations on the initial mechanism of surface oxidation in copper subjected to high temperature. Experimental techniques are described and the results obtained for the effects of temperature, pressure, time, and crystal orientation are presented.

The Response of Aluminium-Spray Coatings to Simulated Abnormal Service Variables. R. S. Smith and N. Stephenson. *Gt. Brit., NGTE Memo. M. 332*, Dec., 1959. 32 pp. Investigation of the effect on aluminum-spray coatings of the following: a rural atmosphere, tap and distilled water, simulated repeated frosts, hydraulic pressure in water followed immediately by rapid heating, static stress, vibration, and dilute and saturated sulphurous acid.

Tungsten Coatings for High-Temperature Service. *Tool Engr.*, June 15, 1960, pp. 109, 110. Presentation of a method of plating tungsten on metal surfaces, using a vapor deposition process. It is noted that complex parts of pure tungsten can be built-up by the same method.

How to Specify Finishes for Magnesium. J. A. Stevens. *Prod. Eng.*, June 6, 1960, pp. 31–35. Presentation of a selection guide to the most suitable finish system, including chemical treatments and organic coatings for best properties and lowest cost.

High Temperature

High Temperature Plastics: Where Do We Stand? W. Brenner. *Materials in Des. Eng.*, June, 1960, pp. 132–134. Survey of the state-of-the-art in the field of organic, semiorganic, and inorganic polymers for long-time (several hundred hours) service at 500°F. and above. It is noted that while substantial progress has been made by utilizing the ablation principle and already known types of polymeric materials in meeting the problem of short-time exposure, the solution to the problem of long-time exposure is being sought in the development of radically new materials.

Four Advanced Power Generators Pose Hot Materials Problems. I—Thermoelectric Generators. *Materials in Des. Eng.*, June, 1960, pp. 134–138. Discussion of the materials suitable for use in, and the physical principles underlying, thermoelectric, magnetohydrodynamic, and thermionic generators and fuel cells.

Metals & Alloys

Ob Anomal'nom Roste Zeren Metallov v Vakuume. L. S. Moroz and Iu. D. Khesin. *AN SSSR Dokl.*, Mar. 11, 1960, pp. 306, 307. In Russian. Discussion of the anomalous growth of metal grains in a vacuum observed in testing the behavior of metals under elevated temperatures.

O Svoistvakh Sootnoshenii Zakona Anizotropnogo Uprochneniia Plasticheskogo Meteriala. D. D. Ivlev. *Prikl. Mat. i Mekh.*, Jan.-Feb., 1960, pp. 144–146. In Russian. Analysis covering the law of anisotropic hardening of plastic materials, leading to hyperbolic equations extending qualitative properties of the ideal plastic material to the case of hardening bodies.

A Mechanism of Deformation of Metals at High Temperatures with Special Reference to the Tension Test and the Creep Test. Shuji Taira, Kichinosuke Tanaka, and Kiyotsugu Ohji. *JSME Bul.*, May, 1960, pp. 228–234. 10 refs. Determination of the three kinds of characteristic functions (strain rate, work hardening, and rate of recovery) in the theory of deformation from the results of constant strain rate tension tests at a temperature of 450°C.

Ob Interpoliatsionnykh Uravneniiakh Sostoianiia Metallov dlia Oblasti Sverkhvysokikh Davlenii. S. B. Kormer and V. D. Urlin. *AN SSSR Dokl.*, Mar. 21, 1960, pp. 542–545. 10 refs. In Russian. Derivation of interpolation equations of state for metals at ultrahigh pressures.

A Study of the Thermal Fatigue Behaviour of Metals: The Effect of Test Conditions on Nickel-Base High-Temperature Alloys. E. Glenny. *Gt. Brit., NGTE Rep. R. 239*, Jan., 1960. 43 pp. 14 refs. Investigation of the significant factors governing the thermal fatigue behavior of nickel-base high-temperature alloys. A laboratory technique with hot and cold fluidized beds as the heating and cooling media is used for the experiments.

Surface Deformation of Aluminum in Fatigue. J. C. Grosskreutz and C. M. Gosselin. *J. Appl. Phys.*, June, 1960, pp. 1127, 1128. USAF-supported presentation of a taper-sectioning technique which overcomes the imperfections of earlier taper-sectioning methods. No intervening treatment of the specimen is necessary, except for casting in a 25% methyl methacrylate—75% butyl methacrylate mixture to facilitate sectioning.

Some Metallographic Observations on the Subsequent Ageing Behaviour of an Aluminium-Zinc-Magnesium Alloy After Room Temperature Fatigue and on the Elevated Temperature Fatigue Behaviour of the Same Alloy. C. A. Stubbington. *Gt. Brit., RAE TN Met. 316*, Jan., 1960. 16 pp.

A Study on the Fatigue Strength of Carbon Steels Under Multiple Repeated Stresses. Toshinori Kōri and Shigemi Sasaki. *JSME Bul.*, May, 1960, pp. 281–286.

Stress Criterion for Fatigue Fracture of Steels. T. Yokobori. *J. Mech. & Phys. Solids*, May, 1960, pp. 81–86. 13 refs. Presentation of an approach to the problem of correlating the microscopic fatigue strength of steels with microscopic explanations of present dislocation theory. The stress concentration or notch effect due to the obstacle itself, against which the dislocations pile up, is taken into account in addition to assuming that stress concentration at the piled-up dislocations plays an important role in fatigue fracture of steels.

Influence of Rest in Stress Alternation on the Fatigue Properties of a Low Carbon Steel at Elevated Temperatures. Shuji Taira, Yasunori Murakami, and Ryoichi Koterazawa. *JSME Bul.*, May, 1960, pp. 242–246.

A Simple Model of a Propagating Crack. A. N. Stroh. *J. Mech. & Phys. Solids*, May, 1960, pp. 119–122. Development of a model for a crack in which surface energy in the Griffith treatment is taken to depend on the temperature and strain rate. It is found that such a crack shows a transition from brittle to ductile behavior as the temperature is raised.

Some Experiments on the Fatigue Life Under Double and Triple Stresses. Yuichi Kawada, Yoshito Sekido, and Shigemi Sasaki. *JSME Bul.*, May, 1960, pp. 275–281. 12 refs. Investigation of low- and high-carbon steel showing that, in the former case, fatigue life is prolonged by secondary and tertiary stresses regardless of whether they are higher or lower than the primary stress. In the latter case, fatigue life was shortened only when the secondary and tertiary stresses were higher than the primary stress.

Ob Opasnosti Mgnovennogo Razrusheniia Elementov Konstruktsii pri Tsiklicheskikh Peregruzkakh. G. V. Uzhik and M. Ia. Gal'perin. *AN SSSR Dokl.*, Apr. 11, 1960, pp. 1046–1048. In Russian. Description of experiments made to determine the causes of sudden failure in steel specimens subjected to cyclic loading.

Influence of Residual Stresses on Fatigue Strength of Plates with Fillet Welded Attachments. T. R. Gurney. *(BWRA Rep. D8/3/59*, Aug., 1959.) *Brit. Welding J.*, June, 1960, pp. 415–430. Presentation of test results for mild steel and light alloys showing that fatigue behavior is directly affected by residual stresses, which can be induced by spot heating as well as by mechanical means.

Influence of Frequency of Stress Cycles on Fatigue at Elevated Temperatures. Shuji Taira and Ryoichi Koterazawa. *JSME Bul.*, May, 1960, pp. 235–241. 14 refs. Results of rotating bending fatigue tests which suggest that the fatigue at elevated temperatures is a rate process and is closely related with the plastic deformation of material under an alternating load.

Effect of Oleophobic Films on Metal Fatigue. H. E. Frankel, J. A. Bennett, and W. L. Holshouser. *J. Res., Sect. C - El*, Apr.-June, 1960, pp. 147–150. 12 refs. Study showing that the fatigue strengths of a low-alloy steel, a magnesium alloy, and a copper-beryllium alloy are increased by coating the specimens with certain polar organic compounds. It is suggested that the effect of the coatings is principally due to their ability to present a barrier to water and oxygen molecules.

A Two-Distribution Interpretation of Fatigue S-N Data. S. R. Swanson. *Can. Aero. J.*, June, 1960, pp. 221–223. Investigation of the statistical behavior of single-level constant-amplitude fatigue endurances, using 2024-T4 aluminum alloy specimens under axial loadings. The pattern of behavior at the "knee" of the S-N curve was discovered to be consistent with a hypothesized rise and decay, respectively, of two endurance distributions, each representing the action of a separate fatigue mechanism. The behavior of these distributions is discussed, statistical evidence is offered for their existence and behavior, and a few notes on the implications of this approach are included.

Introduction to High Temperature Metals. J. C. Merriam. *Materials in Des. Eng., Manual No. 172*, June, 1960, pp. 143–158. Discussion of the problems encountered at temperatures of 1,200° to 2,500°F. Requirements, properties, and data are given for : (1) iron, nickel, and cobalt-base superalloys, (2) refractory metals and alloys, and (3) borderline and potential materials.

Contribution à l'Etude du Phénomène de Portevin-Le Chatelier. Jules Caisso. *France, Min. de l'Air PST 357*, 1960. 70 pp. 46 refs. SDIT, 2 Av. Porte-d'Issy, Paris 15, NF 9.80. In French. Study of the conditions governing the appearance of the Portevin-Le Chatelier phenomenon—i.e., the appearance, development, and disappearance of hatching on the stress diagram as function of temperature and speed.

Non-Metallic Dispersions in Cobalt and Its Alloys. II—Sintered High-Temperature Chromium-Cobalt Alloys. Rudolph Palme. *Cobalt*, June, 1960, pp. 13–25.

Cold-Drawing Ups Nickel's High Temperature Creep Strength. *Space/Aeronautics*, June, 1960, pp. 139, 140, 143.

Ob Integrirovanii Uravnenii Neustanovivsheisia Polzuchesti Tverdykh Tel. P. S. Kuratov and V. I. Rozenblium. *Prikl. Mat. i Mekh.*, Jan.-Feb., 1960, pp. 146–148. In Russian. Derivation of a solution for the unsteady creep in solid bodies, reduced to the calculation of the growth of stress and deformation for successive small time intervals Δt.

Etude Expérimentale de la Déformation à la Surface, Autour et à l'Intérieur de l'Empreinte Brinell. A. Popoff. *France, ONERA NT 55*, 1959. 10 pp. In French. Description of a technique for measuring the plastic deformation of metals. The method is applicable to the study of large localized deformations, in particular, the Brinell case.

Metals & Alloys, Nonferrous

Diagramma Ravnovesiia Troinoi Sistemy Ti-Al-Sn. I. I. Kornilov and T. T. Nartova. *AN SSSR Dokl.*, Apr. 1, 1960, pp. 837–839. In Russian. Study of the equilibrium of ternary Ti-Al-Sn systems in the region bounded by the partial ternary Ti-Ti_3Sn-TiAl system.

Vlastnosti a Použití Hořčíkových Slitin v Leteckém Průmyslu. Karel Straka. *Zpravodaj VZLÚ*, No. 3, 1959, pp. 27–40, 49–54. 22 refs. In Czech. Discussion of the characteristics of magnesium and its alloys in terms of their application to aircraft industry. Also covered is the effect of various additives on the mechanical and physical properties of magnesium alloys, and the low plasticity in the cold state is evaluated in comparison with other alloys. Appended are tables giving main types of magnesium alloys, as well as classification standards used in Czechoslovakia, USSR, USA, Great Britain, France, and Italy.

The Mechanical Properties at Temperatures up to 350°C of Plain and Welded Sheet in Magnesium Alloy ZTY. M. S. Binning and B. Angell. *Gt. Brit., RAE TN Met. 315*, Nov., 1959. 12 pp.

Design Properties and Fabrication Characteristics of Beta Titanium. E. F. Erbin. *Mach. Des.*, June 23, 1960, pp. 132–139. Discussion of the mechanical and high- and low-temperature properties of Ti-13V-11Cr-3Al alloy, including heat treatment, welding, and fabrication procedures recommended.

Nonmetallic Materials

Needed: Textiles for the Space Age. J. H. Ross. *Materials in Des. Eng.*, June, 1960, pp. 138–140. Discussion of the requirements for textiles for space use. The state-of-the-art in their development is studied, and the most pressing areas of research are indicated.

The Behaviour of Glass Reinforced Polyester Laminates in Tension. R. B. Heywood. *Gt. Brit., RAE TN Chem. 1364*, Jan., 1960. 21 pp. Discussion of room-temperature tensile tests made in the warp direction on polyester laminates reinforced with six different types of glass fabric with two types of glass finish. The results are analyzed to show the dependency of strength and stiffness on various parameters, such as the glass resin proportions, the number of plies of fabric, post cure, and premature micro-cracking of the resin.

Glasfaserverstärkte Kunststoffe im Flugzeug- und Fahrzeugbau. K. A. F. Schmidt. *(WGL Meeting, Hamburg, Oct. 14, 1959.) ZFW*, May, 1960, pp. 140–145. 11 refs. In German. Discussion of the characteristics and applications of glass fiber reinforced plastics.

Badania Pewnych Reologicznych Własności Elastooptycznych Kilku Żywic Poliestrowych. II, III. J. T. Pindera. *Rozprawy Inżynierskie*, No. 4, 1959, pp. 481–540. 13 refs. In Polish, with summaries in English and Russian. Investigation of certain rheological properties of some polyester resins for use in photoelasticity.

Testing Methods

Ultra-Short-Time Creep Rupture Equipment Manual. J. S. Ives, Jr. *USAF WADC TR 59-762, Pt. I*, Apr., 1960. 45 pp.

Elastic Limit by the Residual Strain Method Using SR4 and Tuckerman Gages on Aluminum

Alloy. A. W. Brisbane and R. F. Klinger. *USAF WADC TN 59-340*, Mar., 1960. 32 pp. Determination of the "elastic limit" of 7075–T6 aluminum alloy in terms of SR4 and Tuckerman gage indications through the use of residual microstrains following tensile and compressive loading and unloading. Residual strain versus applied load relationships are developed as functions of reference stress level and material and gage history.

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L'Interprétation des Mesures par la Clause de Régularité; Applications, Philosophie de l'Expérience. Pierre Vernotte. *France, Min. de l'Air NT 82*, 1959. 73 pp. SDIT, 2 Av. Porte-d'Issy, Paris 15, Frs. 1,235. In French. Discussion showing that even incomplete data can be interpreted with precision, based on the regularity exhibited by a physical phenomenon. Application is made to the derivation of an experimental curve defined only by a few points.

Differential Equations

Basic Differential Equations. A. D. Kraus. *Elec. Mfg.*, July, 1960, pp. 88–106. 17 refs. Presentation of the derivation, theory, and methods of solving first-order and higher-order differential equations. The application of differential equations to a mass-spring-damper system is analyzed, and several basic concepts are illustrated.

Ob Invariantnykh Poverkhnostiakh Sistemy Dvukh Differentsial'nykh Uravnenii. V. A. Pliss. *AN SSSR Dokl.*, Apr. 11, 1960, pp. 1022–1024. In Russian. Definition of invariant surfaces of a system of two differential equations.

On Nonlinear Ordinary Differential Equations Containing a Parameter. Yasutaka Sibuya. *J. Math. & Mech.*, May, 1960, pp. 369–397. 18 refs. Presentation of a method for solving a system of differential equations containing a complex parameter, variable, and an n-dimensional vector.

A Special Hill's Equation with Discontinuous Coefficients. Harry Hochstadt. *NYU Inst. Math. Sci. Div. Electromagn. Res., Res. Rep. BR-32 (AFOSR TN 60-322)*, Mar., 1960. 17 pp.

The Approximation of Solutions of Non-Linear Differential Equations. M. D. George. *U. Md. Inst. Fluid Dynamics & Appl. Math. TN BN-196 (AFOSR TN 60-329)*, Mar., 1960. 14 pp. Presentation of the sufficient conditions for the convergency of a sequence of operators to a given semigroup of nonlinear operators in a Banach space, with applications to the approximation of solutions of nonlinear partial differential equations by finite-difference methods.

An Iterative Solution of Large Scale Systems of Simultaneous Linear Equations. F. J. Bellar, Jr. *U. Md. Inst. Fluid Dynamics & Appl. Math. TN BN-211 (AFOSR TN 60-550)*, May, 1960. 9 pp. Presentation of an algorithm proposed by Lanczos for the generation of an approximate solution of a large scale system of simultaneous linear equations, improved in such a way that the number of interactions required for a desired degree of accuracy is minimized.

Autosynartetic Solutions of Differential Equations. D. C. Lewis. *RIAS TR 60-12 (AFOSR TN 60-438)*, May, 1960. 58 pp. Extension of Poincaré's theory to cover the perturbation of a solution satisfying a certain functional equation. Theorems covering the degeneracy of an autosynartetic solution, associated bifurcation equations, the influence of certain kinds of first integrals on the degeneracy and on the bifurcation equations, and the phenomena associated with the presence of certain kinds of continuous groups or semigroups of transformations which take a differential system into itself are presented.

Functions & Operators

Nekotorye Voprosy Priblizheniia Pochti-Periodicheskikh Funktsii s Ogranichennym Spektrom. E. A. Bredikhina. *AN SSSR Dokl.*, Apr. 1, 1960, pp. 721–724. In Russian. Analysis covering certain problems in the approximation of quasi-periodic functions with a bounded spectrum.

Ostailliruiushchie Funktsii i ikh Prilozhenie k Nekotorym Zadacham na Beskonechnom Promezhutke. R. A. Mart'ianova. *MVO SSSR VUZ Izv. Matemat.*, No. 2, 1960, pp. 113–128. 10 refs. In Russian. Extension of the method of oscillating functions to the case of an infinite region Ω. The functions are applied to the approximate solution of boundary problems over the interval $[a, \infty]$, $a \geq 0$, the reduction of the boundary problem to that of Cauchy is analyzed, and the stability of solution of the boundary problem is considered.

Obrashchenie Integro-Differentsial'nykh Operatorov s Pomoshch'iu Funktsii Grina. I. D. Cherkasov. *MVO SSSR VUZ Izv. Matemat.*, No. 2, 1960, pp. 223–235. 12 refs. In Russian. Analysis covering the transformation of integral differential operators by means of Green's function. Application to the equations of mathematical physics is considered.

Matrices

An Algorithm for the Factorization of Positive Matrices. D. C. Youla. *USAF RADC TN 60-4*, Apr., 1960. 15 pp.

Numerical Analysis

Analytic Continuation of Random Series. Alexandra Ionescu Tulcea. *J. Math. & Mech.*, May, 1960, pp. 399–410. Study of some analytic aspects of the theory of random series, and of an abstract infinite-dimensional Hilbert space $\mathfrak{IC}$ and the set U of all unitary operators on $\mathfrak{IC}$.

Surface Spherical Harmonic Expansions. V. L. Shapiro. *Rutgers State U. Rep. (AFOSR TN 60-339)*, Mar. 18, 1960. 28 pp. 10 refs. Study of the absolute convergence of surface spherical harmonic expansions on the n-sphere and of the uniqueness of surface spherical harmonics on the two-sphere.

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Metod Chislennogo Resheniia i Chislennogo Analiza Reshenii Odnorodnykh Sistem Lineinykh Algebraicheskikh Uravnenii Obshchego Vida. L. S. Maiants. *AN SSSR Dokl.*, Mar. 1, 1960, pp. 51–54. In Russian. Development of a method for the numerical solution and numerical analysis of solutions for homogeneous systems of linear algebraic equations in the general form.

Ob Ustoichivosti Polozhenii Ravnovesiia v Razryvnykh Sistemakh. M. A. Aizerman and F. R. Gantmakher. *Prikl. Mat. i Mekh.*, Mar.-Apr., 1960, pp. 283–293. 10 refs. In Russian. Analysis covering the stability of equilibrium on discontinuity surfaces for systems of differential equations of the $(1\pm)$ type with arbitrary right-hand sides.

Physical Applications

Free Boundary Problems for Parabolic Equations. III—Dissolution of a Gas Bubble in Liquid. Avner Friedman. *J. Math. & Mech.*, May, 1960, pp. 327–345. Navy-supported study of the behavior of one gas bubble in liquid, not necessarily of the same substance, in which some of the same gas is dissolved. It is shown that even supersaturated solutions are stable in the sense that bubbles cannot grow in them if they are too small initially. The existence and uniqueness of the solution to the problem is proved, and its properties are studied.

Multhopp's Influence Functions and Their Automatic Computation. G. G. Alway. *Quart. J. Mech. & Appl. Math.*, Feb., 1960, pp. 112–118. Presentation of a method to calculate the influence functions arising in Multhopp's subsonic lifting surface theory.

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A Missile Must be Trusty. J. F. Scheer. *Skyline*, No. 2, 1960, pp. 14–19. Discussion of the reliability program used in the fabrication of the Minuteman missile.

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Facet-Eye Camera System is Major Contribution to Satellite Tracking Systems. *Holloman Mo. News Bul.*, Mar., 1960, pp. 4, 10. Description of an instrument which will ultimately employ 25 telescope-orthicon camera "chains," each chain consisting of a telescope, an orthicon camera, a video link, and an image-reproducing oscilloscope tube. The difficulties of timing signal transmission are also discussed.

Ballistics, Re-Entry

Analytical and Numerical Studies of Three-Dimensional Trajectories to the Moon. A. B. Mickelwait and R. C. Booton, Jr. *(IAS Natl. Summer Meeting, Los Angeles, June 16–19, 1959, Paper 59-90.)* *J. Aerospace Sci.*, Aug., 1960, pp. 561–573.

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Guidance, Control, Stability

Control Considerations for a Lunar Soft Landing. Arnold Peske and George Swanlund. *IAS Natl. Summer Meeting, Los Angeles, June 28—July 1, 1960, Paper 60-76.* Members, $0.50; nonmembers, $1.00. 7 pp. Discussion of general requirements on vehicle control during the powered phase of a lunar descent. The factors considered are: fuel use for control, configuration of the control equations, and the capabilities of man during the landing phase.

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The Shape of Tomorrow. C. I. Cummings. *Astronautics*, July, 1960, pp. 24, 25, 91. Discussion of NASA's Ranger project – including the Ranger spacecraft, its instrumentation, and mission – aimed at investigating the cislunar space, the lunar surface, and the planets Mars and Venus.

Rocket Power—Key to Space Supremacy. D. R. Ostrander. *Astronautics*, July, 1960, pp. 22, 89, 90. Discussion of NASA's present and planned launching-vehicle program, including a presentation of vehicles now in the fleet and of the standardized ones being developed for the future.

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Design for a Space-Laboratory. *The Aeroplane & Astronautics*, June 3, 1960, pp. 680, 681. Presentation of the general design of a preassembled laboratory, weighing 35,000 lbs. and capable of maintaining four to six men in orbit for a year, which would be launched by advanced ICBM boosters now under development.

Stations in Space. H. F. Crouch. *(SAE Natl. Aero. Meeting, New York, Apr. 5–8, 1960, Preprint 167A.)* *SAE J.*, May, 1960, pp. 82–85. Discussion of the characteristics of a space station and the use of nuclear rockets as transportation means to and from such stations, as well as means of lifting the station into space. Such a vehicle would be capable of maneuvering in orbit and of controlled re-entry.

Ranger Space "Bus" to Fly Instrument "Passengers" Next Year. *Western Av.*, June, 1960, pp. 10, 11, 40. Discussion of the lunar missions and the instrumentation of the Ranger-A. Other planned missions, including planetary missions, are mentioned.

Boeing Details Design and Assembly Plans for a General-Purpose Space Capsule. W. E. Beall. *(SAE Natl. Aero. Meeting, New York, Apr. 5–8,*

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Ferry to Space. *Vectors*, 2nd Quart., 1960, pp. 5–9. Presentation of a new concept in structural control, utilizing the structural temperature of the vehicle as the primary signal to the control system. The operation of a space ferry during a rendezvous and re-entry mission is discussed.

Elliptical Orbit Characteristics. G. S. Gedeon and B. J. Greer. *ARS J.*, June, 1960, pp. 570–572. Presentation of two working charts which permit the establishment of the orbital characteristics of a satellite after initial launch or after transfer from another orbit. The curves presented are based on two-body equations and cover a range limited by the apogee radius equal to not more than twice the perigee radius.

Interim Definitive Orbit for the Satellite 1958-Gamma, Explorer-III. *U.S., NASA TN D-356*, June, 1960. 490 pp. Presentation of certain position information indicating accuracies for the orbital arcs underlying the ephemeris, and detailed ephemeris information in the form of tables which give the latitude and longitude of the sub-satellite point and the satellite height for each minute of time.

Ionosphere Probes May Have Wide Effect. Barry Miller. *Av. Week & Space Tech.*, June 20, 1960, pp. 235, 237, 241, 245. Discussion of the organization of and the equipment used in a series of upcoming ionospheric sounding experiments aimed at measuring (1) the electron density of the ionosphere at 180 to 600 miles above the earth, (2) the variation of these parameters with time of day season, latitude, and degrees of geomagnetic disturbance, (3) plasma resonance frequency in the vicinity of the sounder, and (4) cosmic noise level in 3 to 15 mc. range.

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Transit: Navy Claims World's First Operational Satellite. James Holahan. *Space/Aeronautics*, June, 1960, pp. 154–157. Presentation of the theory of precise surface navigation by means of the Transit satellite, and description of the essential elements of the payload.

Structural Design of the Tiros Meteorological Satellite. R. W. Northrup. *Western Av.*, May, 1960, pp. 12–14, 16, 46. Discussion of the design criteria and features, and of the analytical techniques used to verify the strength of the structure of the Tiros meteorological satellite.

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Electronic Aids

A System of Automatic Navigation. C. Britnell. *Inst. Navigation J.*, Apr., 1960, pp. 178–186. 14 refs. Description of a computer, the Radio Track Guide, which has been subjected to both air and ground trials and can provide accurate automatic guidance for all anticipated operational conditions in a manner which is of value for both navigational and movement-control purposes.

An Automatic Dead Reckoning Computer. K. Ramsayer. *Inst. Navigation J.*, Apr., 1960, pp. 186–191. Description of a dead-reckoning computer on which position is presented instantaneously on a map.

A Route Direction-Finder. P. Gaudillère. *Inst. Navigation J.*, Apr., 1960, pp. 191–195. Discussion of the design considerations and of the operation of the direction finder which gives an accurate directional reference. It uses two distant transmitters radiating two continuous waves, the frequencies of which are different but very proximate.

A Canadian Doppler System. *Interavia*, June, 1960, pp. 736, 737. Discussion of the design considerations in automatic navigation systems, and detailed description of the design choices made in the CMA-620 systems.

A Pilot's Viewpoint on the Navaid Problem. Peter Eaby. *Aeronautics*, Apr., 1960, pp. 18–23. Discussion of the relative merits in en-route navigation and in holding procedures of the radio compass, the VOR station, and of the Decca Flight Log. The discussion is illustrated by practical examples.

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Nuclear Energy

America's Aircraft Reactor Programme. Roy McLeavy. *Air BP*, No. 15, 1960, pp. 22–26. Discussion of the history of a program aimed at developing a direct-cycle nuclear power system for aircraft. Operating techniques for a hypothetical nuclear aircraft and eventual requirements are also studied.

Tory II-A Engineering Test Reactor Aids Project Pluto. *Av. Week & Space Tech.*, June 20, 1960, pp. 206, 207, 209, 211–229 (ff.). Discussion of the Tory II-A ram-jet-type reactor (which is not flight-type hardware, but whose design requirements are keyed closely to actual flight conditions) including design and testing, its instrumentation system and information display, fuel cost, and problem areas influencing the design.

Pebble Bed Reactor Looks OK for Nuclear Space Vehicles. M. M. Levoy and J. J. Newgard. (*SAE Natl. Aero. Meeting, New York, Apr. 5–8, 1960, Preprint 165B.*) *SAE J.*, June, 1960, pp. 46–50.

Single Reactor All-Nuclear System Favored for Nuclear Aircraft. L. W. Credit. (*SAE Natl. Aero. Meeting, New York, Apr. 5–8, Preprint 169C.*) *SAE J.*, May, 1960, pp. 34–38. Study of three techniques for attaining flight reliability with a nuclear propulsion system equivalent to that of a four-engine chemically-powered aircraft. The influence of each of these techniques on aircraft size and growth potentials is evaluted, and the single reactor all-nuclear aircraft is found to be the optimum design.

Nuclear Engines Offer Good Stability. F. G. McGuire. *Missiles & Rockets*, June 13, 1960, pp. 29, 32, 33. Discussion of the results of an analytical study of a system utilizing a bleed turbine pump drive. It is shown that stability and control of nuclear rocket engines in the one-million-pound-thrust class will not present serious problems.

The Effect of Nuclear Radiation on Electronics. J. W. Clark. *Vectors*, 2nd Quart., 1960, pp. 10–15. Discussion of "rate effects" and "dose effects" in equipment, including facilities necessary for research on radiation. Radiation environments and types of radiation, as well as methods of measuring nuclear radiation are noted.

Nuclear Radiation Damage to Transistors. *Elec. Mfg.*, July, 1960, pp. 78–85, 127. USAF-sponsored study of radiation damage to transistors in an environment equivalent to that of a nuclear explosion. Damage data related to transistor reliability are presented in a series of charts and graphs.

Photography

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Photo-Reconnaissance by Radio. *Interavia*, June, 1960, pp. 734, 735. Discussion of the design, operation, and possible applications of the Photoscan airborne image transmission unit which is fully automatic and transmits the data almost instantaneously from the search area for evaluation.

Physics

The Problem of Evolution in General Relativity. W. B. Bonnor. *J. Math. & Mech.*, May, 1960, pp. 439–444. Discussion, using two illustrative examples, showing that the problem of evolution in general relativity need have no unique solution determined by continuity alone if matter is present as a perfect fluid.

Intrinsic Form of the Characteristic Relations for a Perfect Compressible Fluid in General Relativity and Non-Steady Newtonian Mechanics. N. Coburn. *J. Math. & Mech.*, May, 1960, pp. 421–437. 10 refs. Presentation, in intrinsic form, of the equations of motion and continuity of an isentropic, perfect, non-self-gravitating fluid in general relativity, obtained by the use of the relations between the vector along a worldline, the normal to a characteristic surface, and a vector along the bicharacteristic corresponding to this normal.

Solution of the Equations of Motion in a Magnetic Field, for an Isotropic Body in an Infinite Space Assuming Perfect Electric Conductivity. Sylwester Kaliski. *Vibration Prob. Proc.*, No. 3, 1960, pp. 53–67.

Study of the Mechanism of Endothermic Reactions Photosensitized on Solid Surfaces. J. G. Calvert. *Ohio State U. Res. Found. (P-840) Final Rep. (AFCRC TR 60-222)*, Dec., 1959. 20 pp. 11 refs. Investigation of photochemical systems for the conversion of solar energy to chemical or electrical energy. The nature of chemical changes involved in CdS, CdSe, and CdTe systems and the mechanism of energy conversion in them are examined.

Dynamical Equations of Motion Coupled with the Field of Temperatures and Resolving Functions for Elastic and Inelastic Anisotropic Bodies in the Magnetic Field. Sylwester Kaliski and Jan Petykiewicz. *Vibration Prob. Proc.*, No. 3, 1960, pp. 81–94.

Some Comments on Statistical Thermodynamics. Ragnar Liljeblad. *ASEA Res.*, No. 3, 1959, pp. 29–40. Presentation of an attempt to correlate the classical Boltzmann, Bose-Einstein, and Fermi statistics by means of a modification of their presentation.

Paradoks Chasov pri Dvizhenii Zariazhennykh Chastits v Magnitnom Pole. A. A. Sokolov. *AN SSSR Dokl.*, Mar. 1, 1960, pp. 75–77. In Russian. Application of the relativistic invariant equation to study the clock paradox in the relativistic motion of charged particles in a magnetic field.

Equation of State and Phase Transition of the Spherical Lattice Gas. Walter Pressman and J. B. Keller. *NYU Inst. Math. Sci. Div. Electromagn. Res., Res. Rep. HT-5 (AFOSR TN 60-297)*, Feb., 1960. 22 pp.

Atomic Clocks for Space Experiments. P. L. Bender. *Astronautics*, July, 1960, pp. 37, 70, 71. Discussion comparing the cesium-beam, rubidium-vapor, and ammonia-maser types of atomic frequency standards, and pointing out their use in checking the general theory of relativity and in space-vehicle tracking.

Astrophysics

Planetary Astronomy from Satellite-Substitute Vehicles. II—A Survey of Physical Problems of the Nearer Planets and a Review of Observational Techniques Applicable to Balloon-Borne Telescope Systems. Gérard de Vaucouleurs. *USAF MDC TN 59-37*, Dec., 1959. 121 pp. 123 refs.

Ionization of a Static Interplanetary Gas and Expected Emission Lines from This Gas. H. N. Rundle. *Planetary & Space Sci.*, Apr., 1960, pp. 86–98. 31 refs. Analysis of the degree of ionization of hydrogen and helium in a static interplanetary gas. The expected intensities of the more intense helium emission lines in the visible and infra-red regions are given as a function of electron density and kinetic temperature.

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Eksperimental'naia Proverka Gipotezy o Prirode Magnitnogo Skloneniia. V. V. Shuleikin. *AN SSSR Dokl.*, Feb. 11, 1960, pp. 1015–1018. In Russian. Description of studies made to verify experimentally the hypothesis concerning the nature of magnetic inclination, emphasizing the role of tellurian currents in oceans.

The Effect of Topography and Geology on Telluric Currents. E. M. Wescott and V. P. Hessler. *U. Alaska Geophys. Inst. Sci. Rep. 3 (AFCRC TN 60-431)*, Apr., 1960. 60 pp. 25 refs.

Earth Current Activity at College Alaska, 1955–1958. V. P. Hessler and E. M. Wescott. *U. Alaska Geophys. Inst. Sci. Rep. 2 (AFCRC TN 60-293)*, Feb., 1960. 63 pp. 18 refs.

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Properties of the Upper Atmosphere and Their Relation to the Radiation Belts of the Earth. S. F. Singer. *Planetary & Space Sci.*, Apr., 1960, pp. 165–173. 16 refs. USAF-supported presentation of a new theory which gives the distribution of density with altitude for a planetary exosphere in the absence of thermodynamic equilibrium. The results differ considerably from those calculated on the basis of a hydrostatic equation. Using the theoretical distribution for the hydrogen exosphere, the complete development of a magnetic storm as a function of time, including the distribution around the earth of trapped protons and their magnetic effects, is calculated.

Twilight Intensity at 20° Elevation. F. Volz and R. M. Goody. *Harvard U. Div. Eng. & Appl. Phys. BHMO Sci. Rep. 1 (AFCRC TN 60-284)*, Jan., 1960. 46 pp. 35 refs.

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I—Density of Neutral Gas in a Planetary Exosphere. J. C. Brandt and J. W. Chamberlain. **II–Distribution of Density in a Planetary Exo-**

sphere. E. J. Öpik and S. F. Singer. *Phys. Fluids*, May-June, 1960, pp. 485–488. 17 refs. Discussion considering the merits of a theory proposed by Öpik and Singer for the distribution in planetary exosphere of the ballistic component of density.

Physics of Artificial Electron Clouds. F. F. Marmo, L. M. Aschenbrand, and J. Pressman. *ARS J.*, June, 1960, pp. 523–530. 13 refs. Army-sponsored summary of the results and analysis of seven rocket experiments, designed to systematically study the physics of the generation of artificial electron clouds in the upper atmosphere.

K Voprosu o Zavisimosti Struktury Zheleznykh Meteoritov ot Khimicheskogo Sostava. A. A. Iavnel'. *AN SSSR Dokl.*, Apr. 11, 1960, pp. 1049–1052. 10 refs. In Russian. Tentative determination of the relationship between the composition and the structure of iron meteorities, based on available data.

Elektricheskii Razriad pri Prolete Meteorov v Atmosfere Zemli. V. P. Dokuchaev. *AN SSSR Dokl.*, Mar. 1, 1960, pp. 78–81. 14 refs. In Russian. Study covering the electric discharge caused by meteorites moving through the terrestrial atmosphere.

Meteoritic Dust Measured from Explorer I. Maurice Dubin. *Planetary & Space Sci.*, Apr., 1960, pp. 121–129. Presentation of measurements of the impacts of meteorites upon the cylindrical shell of the satellite Alpha 1958. A description of the instrumentation, the calibration procedure, and the amount and type of data recorded at the ground stations are included.

Solar Radio Bursts and Cosmic Rays. A. R. Thompson and A. Maxwell. *Planetary & Space Sci.*, Apr., 1960, pp. 104–109. 21 refs. Discussion using cosmic ray intensity and solar radio data obtained over the two-year period of October 1956–September 1958 to disprove the current theories correlating fast drift bursts and cosmic ray increases on the earth.

Solar Particles and Cosmic Rays. K. A. Anderson. *Sci. Am.*, June, 1960, pp. 64–71. Discussion examining the source of cosmic rays. It is suggested that magnetic fields in the galaxy constitute an "accelerator" for cosmic rays.

Sidereal Anisotropy of High Energy Cosmic Rays. II. I. Escobar, N. Nerurkar, and R. Weil. *Planetary & Space Sci.*, Apr., 1960, pp. 187–192. Presentation of the results obtained from a second period of operation of an extensive shower monitor located at Chacaltaya, Bolivia. The results are shown to be consistent with those obtained during the first period of operation.

Angular Displacement of a Magnetized Sphere by the Terrestrial Magnetic Field During Vertical Descent. M. H. Hewitt. *ARS J.*, June, 1960, p. 558.

Ionospheric Electron Densities for Washington D. C., Panama, Talara, and Huancayo for April-May-June, 1958. E. R. Schmerling. *Penn. State U. IRL Sci. Rep. 128 (AFCRC TN 60-267)*, Jan. 15, 1960. 87 pp.

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Astronomical Observations by Means of Highly Sensitive Electronic Light Intensification. R. K. H. Gebel, Lee Devol, and L. R. Wylie. *USAF WADC TN 59-404*, Mar., 1960. 24 pp. 31 refs. Discussion of the advantages of observing and photographing celestial bodies with a light amplifier which uses the closed circuit television principle. The image-converter system and the closed circuit television system are described.

Scattering Properties of Atmospheric Aerosols. R. S. Fraser. *U. Calif. Dept. Meteorology Sci. Rep. 2 (AFCRC TN 60-256)*, Oct., 1959. 183 pp. 57 refs.

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Mighty Midget of Atomic Power. *Skyline*, No. 2, 1960, pp. 30, 34, 35. Discussion of the lightweight compact thermal reactor, developed for the SNAP 2 program. Electrical power requirements for space missions, weight considerations, and application potential are noted.

The "Not So Auxiliary" Power Systems. H. R. Shows. *Aircraft & Missiles*, July, 1960, pp. 28–31. Presentation of the "allocation model" developed to facilitate the assigning of manpower, facilities, and funds to expedite research, including a brief description of some research areas.

Jet & Turbine

Beitrag zur Anwendung der Schleierkühlung von Gasturbinenschaufeln. F. J. Geller. *DVL Bericht No. 104*, Apr., 1960. 116 pp. 22 refs. Westdeutscher Verlag, Köln & Opladen. In German. Discussion of the problem of turbine-blade cooling in connection with increased gas temperatures for better turbine performance. Various methods of air, liquid, and transpiration cooling are evaluated in terms of the thermal resistance of component materials.

General Electric Turbofan; Designing and Testing the CJ805-23. R. E. Weymouth. *Shell Av. News*, May, 1960, pp. 17–22. Discussion of the development, design, performance characteristics, and test program of CJ805-23 turbofan which will power the Convair 600 and the Sud Aviation Caravelle VII twin-engine jet.

O Problémech při Vývoji Proudového Motoru. Oldřich Buňata. *Zpravodaj VZLÚ*, No. 3, 1959, pp. 11–14. In Czech. Discussion of problems in jet engine design and development, covering the planned performance characteristics, coordination of the compressor and the turbine, tests of the engine and its components, and evaluation of these tests.

Power for an Airline. B. S. Shenstone and H. G. Rossiter. *Shell Av. News*, Mar., 1960, pp. 15–20. Abridged. Discussion of the qualities of an engine necessary for use in commercial transports.

Selection and Design of Thrust Reversers for Jet Aircraft. J. C. Pickerd. *IAS Natl. Summer Meeting, Los Angeles, June 28–July 1, 1960, Paper 60-77.* Members, $0.50; nonmembers, $1.00. 19 pp. Discussion of the factors influencing ground use thrust reverser design, preliminary design, and compatibility of a thrust reverser with an airplane. Typical performance data are surveyed.

Rocket

Combustion Instability in Solid Propellant Rocket Motors. E. W. Price. *ARS J.*, June, 1960, pp. 574–576; Discussion, W. Nachbar and L. Green, Jr., pp. 576, 577. Presentation of experimental results suggesting that burning rate increases during oscillatory combustion reflect a mechanism much like the more familiar erosive burning phenomenon of steady-state burning.

Controllable Solid Rockets for Space Vehicles. K. R. Stehling. *Interavia*, June, 1960, pp. 745, 746. Discussion of the advantages and problems in solid propellant propulsion.

Large Solid-Propellent Motors. J. H. Crook. *The Aeroplane & Astronautics*, May 27, 1960, pp. 650–652. Discussion of the composition of solid propellants, the charge design, and design considerations necessitated by the use of solid propellants.

Solid Power for Thrust-Vector Steering. R. L. Robinson. *Aircraft & Missiles*, July, 1960, pp. 44–46. Comparative discussion of five basic systems for thrust-steering control.

Approximation of Optimum Thrust Nozzle Contour. G. V. R. Rao. *ARS J.*, June, 1960, p. 561. Presentation of a single geometric method for establishing an optimum thrust contour to aid in determining weight and cooling requirements.

Flight Rating Test Demonstration of the XLR99-RM-1 Rocket Engine. R. W. Seaman and D. S. Smith. *IAS Natl. Summer Meeting, Los Angeles, June 28–July 1, 1960, Paper 60-88.* Members, $0.50; nonmembers, $1.00. 19 pp. Presentation of design characteristics of the variable-thrust, liquid rocket engine for the X-15, and discussion of the flight rating test demonstration program. The effects of these demonstration requirements upon design philosophy, and the results of the more unique test conditions are described.

Production

Metalworking

High Energy Rates Shape Parts. E. W. Feddersen. (*SAE Natl. Aero. Meeting, New York, Apr. 5–8, 1960, Preprint 160C.*) *SAE J.*, May, 1960, pp. 39–45. Presentation of the explosive, hydroelectric, and pneumatic-mechanical methods of forming which have the advantage of lower tooling and finishing costs.

Contour-Etching of Steel. P. F. Langstone, D. C. Hoyle, and J. H. Adams. *Aircraft Prod.*, June, 1960, pp. 218–225. Presentation of techniques for the chemical contouring of one per cent chromium-molybdenum steel, including the composition of the etchant specified and the basic formulation of the maskants that were adopted.

Avro Stretcher. *Aircraft Prod.*, June, 1960, pp. 206–215. Discussion of the design, operation, and capacity of the 250-ton twin-head stretch-forming machine, capable of manipulating panels up to 50 ft. in length and 6.5 ft. in width.

Forming Beryllium Sheet. H. A. Jahnle. *Prod. Eng.*, June 20, 1960, pp. 72–75. Discussion of the properties of beryllium metal and sheet, and procedures used when subjecting beryllium to shearing, bending, deep-drawing, brazing, spot welding, and arc welding. Precautionary measures in avoiding toxicity hazards are also noted.

High-Energy Forming Methods—A Critical Review. W. W. Wood. *Tool Engr.*, June 15, 1960, pp. 93–105. Discussion of the high-mass, high-velocity, and high-temperature forming methods, covering principles involved and materials and types of parts suitable for each method.

Rocket Motor Case Material Evaluation by Pressure Vessel Testing. C. W. Haynes and P. J. Valdez. *IAS Natl. Summer Meeting, Los Angeles, June 28–July 1, 1960, Paper 60-72.* Members, $0.50; nonmembers, $1.00. 11 pp. Discussion of test results obtained with AMS 6434 and PH 15–7 Mo alloy steels and H-11 steel. The optimum tempering range is determined, and the effects of such variables as weld mismatch, porosity, improper weld repairs, ground flush welds, and ovality are examined.

Machining Nimonic; Recommended Practice in the Processing of the Wiggin High-Nickel Alloys. *Aircraft Prod.*, June, 1960, pp. 236–239.

Aircraft and Missile Alloys Getting Tougher to Machine. Michael Field. (*SAE Natl. Aero. Meeting, New York, Apr. 5–8, 1960, Preprint 160A.*) *SAE J.*, June, 1960, pp. 86–93.

New Alloys for Brazing Heat-Resisting Alloys. W. Feduska. (*AWS 41st Annual Meeting, Los Angeles, Apr. 25–29, 1960.*) *Welding J. Res. Suppl.*, July, 1960, pp. 292-s–300-s. Discussion of an investigation leading to the development of low-melting nickel-palladium base brazing alloys, containing additions of beryllium and/or silicon. Theoretical considerations concerning ductility and wettability, development procedure, and alloy characteristics' evaluations are included.

Techniques for Welding Al-Mg Alloys. D. M. Daley, Jr. (*AWS 40th Annual Meeting, Chicago, Apr. 6–10, 1959.*) *Welding J. Res. Suppl.*, July, 1960, pp. 301-s–305-s. Discussion of the role of material cleaning procedures, welding conditions, and adequate tools and fixtures in producing superior quality fusion welds with aluminum-magnesium alloys.

High-Frequency Resistance Welding. *Aircraft & Missiles*, July, 1960, pp. 54, 55. Presentation of a technique combining speed with quality in complicated welded shapes. Metals being joined include zirconium and titanium.

Multiple Brazing Process. G. D. Cremer and R. S. Mueller. *Welding J.*, June, 1960, pp. 592–599. Presentation of the principles and techniques involved in high-temperature corrosion-resistant multiple brazing. Application possibilities and advantages are discussed and illustrated on an experimental light-weight sheet-metal honeycomb turbine seal and on a brazed pneumatic control instrument designed for turbojet applications.

The Welding and Brazing of Certain Cobalt-Containing Alloys. W. J. Lepkowski and R. E. Monroe. *Cobalt*, June, 1960, pp. 6–12. 21 refs. Review of the processes and techniques used to produce metallurgical bonds, not including hard surfacing or overlaying. Welding processes and techniques are discussed according to the base metal, while brazing techniques are presented in terms of brazing alloys.

Dip Brazing Bonds Missile Metals Efficiently. Mel Schwartz. *Tool Engr.*, June 15, 1960, pp. 87, 88. Presentation of the dip brazing method which efficiently joins high-temperature metals, avoids oxidation embrittlement problems, and produces joints capable of withstanding 5,000 psi.

Weldless Steel Cases Now Possible. J. F. Judge. *Missiles & Rockets*, June 6, 1960, pp. 31–34. Discussion of a new technique for fabricating solid rocket motor cases using overlapping seamless rings with adhesive bonding. The performance of the joints in pressure vessel assemblies and burst tests is also studied.

The Science of Arc Welding. III—What the Arc Does. C. E. Jackson. *Welding J. Res. Suppl.*, June, 1960, pp. 225-s–230-s. 28 refs. Discussion of the performance characteristics of the consumable-electrode welding arc and of the tungsten arc. Relationships governing the melting rate of the electrode, penetration below the level of the crater, and effect of the welding technique on the melting ratio and nugget area are studied.

Production Metallizing Machines. Lloyd Manuel. *Brit. Welding J.*, May, 1960, pp. 323–326. Review of the considerations necessary when deciding the degree of automation required for any given machine and of the requirements necessary to incorporate good metalizing practice. Some of the automatic metallizing machines now operating in full production are also briefly discussed.

Hard-Facing with "Stellite" Powders. J. R. Gault. *Brit. Welding J.*, May, 1960, pp. 318–323. Presentation of the spray fuze process and

the powder weld technique, both using "Deloro Stellite" cobalt-base materials.

Nonmetalworking

A Technique for Producing Glass-Reinforced Foam-Filled Plastic Model Propeller Blades. A. J. Bowker and L. A. J. Pelland. *Canada, NRC Aero. Rep. LR-273*, Jan., 1960. 28 pp. 12 refs. Description of a procedure for making foam-filled glass-reinforced model plastic propeller blades. The resulting blade is compared with similar blades of wood and aluminum, and it is shown that the plastic blade compares favorably in all respects except strength, where aluminum proves more advantageous.

Production Engineering

The Examination of Thin Round Objects by Means of Ultrasonic Surface Waves. W. Grabendoerfer. (*Stahl und Eisen*, No. 19, 1955, pp. 1273–1275.) *Gt. Brit., MA TIL/T4918*, Feb., 1960. 4 pp. Translation.

Blade-Inspection. *Aircraft Prod.*, June, 1960, pp. 226–233. Discussion of the design and operating principles of an optical-mechanical projector which permits the examination of profile and makes possible the accurate measurement of any errors in the lean or twist of a blade.

"Cold" Testing Techniques. E. C. Madsen. *Auto. Control*, May, 1960, pp. 31–33. Discussion of the techniques using automatic circuit-analyzing test equipment in the checking of modular electronic subassemblies on the Atlas missile production line. Human errors are eliminated through the use of perforated programing tape. Tests of direct-current resistance, continuity, leakage resistance, and impedance are programed to check the completed subassembly for correct selection, placement, and connection of parts before normal power and signals are applied.

Tooling

Laminating Process Simplifies Tooling. Benjamin Sokol. *Tool Engr.*, July, 1960, pp. 39–42. Presentation of a technique of building laminates which circumvents the pressure curing requirement for accurate mold reproduction by making the laminate a self-restraining unit in conjunction with the mold itself. The construction of a large paraboloid reflector of glass cloth and epoxy resins is described to illustrate the process.

Propellers

New Problem Areas in Aircraft Propeller Design. G. Rosen. (*CAI Mid-Season Meeting, Edmonton, Feb. 20, 1960.*) *Can. Aero. J.*, June, 1960, pp. 213–220. Presentation of the new problem areas being generated by the more stringent performance requirements of advanced aircraft. Some of the current research and development efforts to provide the required new technologies are outlined.

Reliability

Special Issue: A Manual of Reliability. *Prod. Eng.*, May 16, 1960, pp. 65–96. *Partial Contents:* What is Reliability. How to Design for Reliability. How to Raise Reliability. The Human Factor in Reliability. The Importance of Failure Analysis. Measurement vs Calculation of Reliability. Statistical Tools for Reliability Tests.

Reliability in Systems Design. M. L. Miller. *Elec. Mfg.*, July, 1960, pp. 107–111. Presentation of a step-by-step procedure for reliability in design, illustrated by the example of a six-tube electronic circuit.

Research, Research Facilities

Instrumentation for Exploding Wire Research. Norman Chase, Norbert Hankin, and Francis Webb. *Electronics*, July 1, 1960, pp. 43–45. Army-supported discussion of electrical explosion of fine metallic wire for spaceship propulsion and optical radar use. Circuits for both detonation and instrumentation are described.

"Show Me" the Uses of Closed Circuit Television Development. Alan Cross. *Aeronautics*, Apr., 1960, pp. 56–58, 61. Survey of the uses of closed circuit television in research testing in wind tunnels, flight tests, the development and testing of aircraft power units, and in investigations of the effect of high-speed flying on the human body. Functions facilitating air travel, both from the viewpoint of airline operators and passengers, are also discussed.

Determination of Pitch and Yaw Rates of Models in Free-Flight Ranges by Magnetic Induction. B. S. Golosman. *J. Aerospace Sci.*, Aug., 1960, pp. 638, 639.

Environmental Physical Standards. J. W. Burgess. *Sperry Eng. Rev.*, June, 1960, pp. 36–44. Presentation of methods and equipment used to relate the conditions produced by environmental testing equipment (temperature, relative humidity, absolute pressure, and mechanical vibration) directly to NBS' standards to a known degree of accuracy. Methods of calculating errors are outlined, and procedures and techniques adopted in setting up secondary reference standards are discussed.

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Stationary Temperature Fields in Multilayer Cylindrical Tubes. Václav Vodička. *ZAMM*, Apr., 1960, pp. 165–170. Generalization of previously obtained results for the case of hollow infinite cylinders composed of n layers. The case of a circular, as well as that of an elliptical, cylinder is covered.

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VTOL & STOL

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VTOLs and STOLs: Specifications and Performance. *Space/Aeronautics*, June, 1960, pp. 62–66, 69, 70, 73–108 (ff.).

The Development of the STOL Airplane. A. F. MacDonald. (*CAI Mid-Season Meeting, Edmonton, Feb. 19, 1960.*) *Can. Aero. J.*, June, 1960, pp. 203–206. Discussion of the performance capabilities and applications of the De Havilland Beaver, Otter, and DHC-4 Caribou. Instances where these aircraft were used are presented.

Survey of Short and Vertical Take-Off Aircraft. *Interavia*, May, 1960, pp. 556–560. Discussion of the principal methods of achieving vertical or short take-off and of the requirements for V/STOL aircraft, noting a trend toward a jet-supported VTOL supersonic aircraft.

Kombinierte Strahlantriebsanlage für Kurzstart und Kurzlandung. *Luftfahrttechnik*, May 10, 1960, pp. 149, 150. In German. Description of a power plant arrangement, developed by Fiat, featuring several turbojets and designed for short take-off and landing aircraft.

V/STOL Cargo Airplane Characteristics. W. C. J. Garrard. *IAS Natl. Summer Meeting, Los Angeles, June 28–July 1, 1960, Paper 60-69.* Members, $0.50; nonmembers, $1.00. 23 pp. Discussion of the performance capabilities and cost of medium size, unpressurized, low subsonic speed, cargo or passenger-carrying VTOL vehicles, including a comparison with STOL airplanes, with the primary object of investigating whether the military and commercial transport capabilities of the helicopter are likely to be surpassed in the near future by different VTOL designs.

Some Notes on the Ground Effect Phenomena and the Princeton Program. T. E. Sweeney. *Princeton U. Dept. Aero. Eng. Rep. 493*, Dec., 1959. 30 pp. Army-sponsored discussion of the principles of ground effect machines in nontechnical terms and description of various GEM's developed at Princeton University.

The Promise of the Ground-Effect Machine. *Aeronautics*, June, 1960, pp. 61, 62. Discussion of the advantages offered by ground-effect machines, their application possibilities, and design and economic considerations.

SC. 1. *Flight*, June 10, 1960, pp. 793–798, cutaway drawing. (Also in *The Aeroplane & Astronautics*, June 10, 1960, pp. 701–709.) Discussion of the developmental history, design, power plants, and stabilization and control systems of the fully jet-supported, flat-rising SC.1 VTOL research aircraft.

Design of Ground Effect Vehicles. W. R. Bertelsen. *Can. Aero. J.*, June, 1960, pp. 223–225. Discussion of the design requirements for ground effect vehicles concluding that the simplicity of single fan, single engine design with tilting control and propulsion provides the most economical and efficient machine.

The Development of the Aerodyne. A. M. Lippisch. *Interavia*, May, 1960, pp. 569, 572, 573. Discussion of design considerations and aerodynamic principles fundamental to wingless aircraft.

GEM State of the Art: The Design Potential. Victor de Biasi. *Space/Aeronautics*, June, 1960, pp. 47–50. Review of design problems and possibilities of ground effect machines as affected primarily by augmentation characteristics.

GEM State of the Art: The Basic Configurations. T. E. Sweeney and W. B. Nixon. *Space/Aeronautics*, June, 1960, pp. 50–52. Study of open-plenum and peripheral-jet ground effect machines, GEM-fixed wing hybrids, and ram-wing vehicles. Stability and control problems are treated in detail.

GEMs: Specifications and Performance. *Space/Aeronautics*, June, 1960, pp. 53–55.

Aircraft Without Wings. S. G. Hooker. *Aeronautics*, June, 1960, pp. 22–25. Discussion of the type of engine which might be used for wingless vehicles, and of the performance capacity of machines of this type.

A VTOL Power Plant Project. Grenville Manton. *Aeronautics*, June, 1960, p. 31. Discussion of a power unit design featuring two turbojet engines placed horizontally and side by side with a third turbine, used to drive a ducted lift fan, incorporated in the unit.

Practical V/STOL—The XV-3 Story. C. E. Davis. *AHS Newsletter*, June, 1960, pp. 3–10. Discussion of the specifications, design features, systems, tests, and evaluation flights of the XV-3 fixed-wing, tilting-prop convertiplane.

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REVIEWS OF *Books*

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AERODYNAMICS. FLUID MECHANICS

Incompressible Aerodynamics; An Account of the Theory and Observation of the Steady Flow of Incompressible Fluid Past Aerofoils, Wings, and Other Bodies. Edited by Bryan Thwaites. Oxford, The Clarendon Press; New York, Oxford University Press; 1960. 636 pp. $12. 75*s*.

The present volume is the first in a new series, the Fluid Motion Memoirs, which is sponsored by the British Aeronautical Research Council, and is a synthesis of original contributions by many well-known aeronautical scientists. It is mainly concerned with the uniform flow of fluid past certain kinds of body, and with the methods by which we may predict the physical characteristics of such flow. However, its scope is limited in two important respects: the flows chosen for study are all more or less closely related to the problems of the flight of aircraft, and phenomena associated with the compressibility of fluid or with the unsteadiness of its flow are, as a general rule, ignored.

Contents: 1, Some General Principles. 2, The Calculation of the Boundary Layer. 3, Theoretical Models of Real Flows. 4, Uniform Inviscid Flow Past Aerofoils. 5, Uniform Viscous Flow Past Aerofoils. 6, Boundary-Layer Control. 7, The Displacement Effect of Wings in Uniform Flow. 8, The Lifting Effect of Wings in Uniform Flow. 9, Uniform Flow Past Bodies of Revolution. 10, Uniform Flows Past Joined Bodies. 11, Rotary Flows. 12, Some Miscellaneous Topics. References and Author Index. Subject Index.

Dynamics of Conducting Gases; Proceedings of the Third Biennial Gas Dynamics Symposium, August 24–26, 1959. Edited by Ali Bulent Cambel and John B. Fenn. Sponsored by American Rocket Society and Northwestern University. Evanston, Ill., Northwestern University Press, 1960. 212 pp. $12.50.

Contents: Introduction, T. von Kármán. *Part 1, Elementary Processes and Properties in Ionized Gases.* The Conductivity of an Ionized Gas in a Magnetic Field, W. P. Allis and S. J. Buchsbaum. Some Properties of a Hydrogen Plasma, R. A. Gross and C. L. Eisen. The Statistical Mechanics of the Approach to Equilibrium in Gases, I. Prigogine. Irreversible Processes in a Plasma: Effect of Long Range Forces R. Balescu. Relaxation Processes in Plasma,, H. F. Calcote.

Part 2, Theoretical Considerations on the Interaction of Magnetic Fields and Flow of Ionized Gases. Some Solutions of the Macroscopic Equations of Magnetohydrodynamics, W. R. Sears. A Microscopic Analysis of Magneto-Gas-Dynamics, E. E. Covert. Magnetohydrodynamics in the Limit of Small Inertial Forces, R. X. Meyer. Axially Symmetric Hydromagnetic Channel Flow, F. D. Hains, Y. A. Yoler, and E. Ehlers.

Part 3, Laboratory Experience with Flow of Ionized Gases. Experimental Studies on Plasma Dynamics, W. H. Bostick, J. Nankivell, S. Koslov, and G. Schmidt. Applied Magnetohydrodynamics at Avco-Everett Research Laboratory, M. Camac and G. S. Janes. Techniques for Producing Plasma Jets, J. A. Browning. Electromagnetic Shock Tubes, R. W. Ziemer.

Part 4, Applications of Magneto-Gasdynamic Effects. Optimum Power Generation Using a Plasma as the Working Fluid, J. L. Neuringer. Space Propulsion Engines—A Problem in Production of High Velocity Gases, M. L. Ghai. The Electromagnetic Pinch Effect for Space Propulsion, A. E. Kunen and W. McIlroy. Plasma Acceleration by Guided Microwaves, Robert V. Hess and Karlheinz Thom. Considerations in the Design of a Steady DC Plasma Accelerator, G. P. Wood and A. F. Carter.

Symposium of Plasma Dynamics. Francis H. Clauser, General Editor. Sponsored by the Air Force Office of Scientific Research and Prepared under the auspices of the National Academy of Sciences. Reading, Mass., Addison-Wesley Publishing Co., Inc., 1960. 369 pp. $12.50.

This volume is based on the transcribed proceedings of the sessions held at Woods Hole, Mass., June 9–13, 1958. No formal papers were presented. Each session had a chairman, an introductory speaker to present the subject for discussion, and an editor to prepare the material for publication. The topics reported are: (1) experimental research on high-temperature plasmas, (2) the problems of thermonuclear fusion and high-temperature plasmas, (3) gaseous electronics phenomena, (4) the dynamics of electron beams, (5) statistical plasma mechanics, (6) continuum plasma dynamics, (7) flight magnetohydrodynamics, (8) solar, planetary, and interplanetary magnetohydrodynamics, and (9) cosmical magnetohydrodynamics.

The volume closes with an index and a bibliography of over 1,000 references to plasma dynamics, waves boundary layers, gas discharges, thermonuclear, fusion, electron beams, aerodynamics, propulsion, and heat transfer.

Aero-Thermodynamics and Flow in Turbomachines. Michael H. Vavra. New York, John Wiley & Sons, Inc., 1960. 609 pp. $14.50.

In Part 1 of this book, which is intended for engineers and graduate students, the fundamental relations for the analysis of arbitrary flows are derived from general principles with the help of vectors and, to a minor degree, with dyadics. These general principles of fluid mechanics and thermodynamics are those that apply to any flow of compressible media, with due regard for energy changes and arbitrary boundary conditions. The author's approach emphasizes basic physical processes rather than empirical methods connected with particular machines, so that this first part can serve as a basis for the analysis of flows in fields other than that of turbomachines.

Part 2 treats flows of more special character, or flows which are idealized either with respect to the properties of the fluids, or the thermodynamic process they undergo. Part 3 is more directly concerned with flows in turbomachines. However, not all aspects of this type of flow are covered since the author is primarily concerned with flow conditions at the design or normal operating point and does not deal with methods for the establishing of performance maps. The book closes with appendixes devoted to a review of vector analysis, an introduction to operations involving dyadics, and tables of optimum operating conditions of axial turbine stages.

Dr. Vavra is Professor of Aeronautics, U.S. Naval Postgraduate School, Monterey, Calif.

Spray Literature Abstracts. Compiled and Edited by Kalman J. DeJuhasz. With Contributions by E. A. Scicchitano. Published with the Support of the National Science Foundation. New York, A.S.M.E., 1959. 383 pp. $12.

This compilation comprises over 1,300 literature items dealing with the scientific, technical, and industrial aspects of sprays. The period covered is 1880 to 1958, inclusive.

The entries contain full bibliographic data and, in most cases, detailed abstracts of articles, papers, bulletins, reports, book chapters, and other literature dealing with the applications of sprays and their scientific aspects: fuel sprays for furnaces, internal combustion engines, gas turbines, and rockets; sprays in industrial processes for evaporation, drying, humidification, cooling, air conditioning, and chemical reactions; atmospheric sprays, such as rain, fog, haze, sleet and snow—their formation, evaporation, and freezing; agricultural sprays for sprinkling and pest, fungus, and weed control; fire-fighting sprays, as in sprinkler systems and in fire-smothering fogs; aerosols for medical, disinfecting, therapeutic, and air-conditioning purposes; and sprays and fogs for military purposes in defense and attack.

DICTIONARIES

Aerospace Dictionary. Frank Gaynor. New York, Philosophical Library, 1960. 260 pp. $6.00.

This dictionary contains about 2,000 entries on rocketry and astronautics, guidance systems, satellites, telemetering devices, manned space flight, re-entry phenomena, celestial mechanics, optical and radio astronomy, and aeronautical science.

Acronyms Dictionary; A Guide to Alphabetic Designations, Contractions, and Initialisms. Detroit, Gale Research Co., 1960. 211 pp. $10.

In addition to the acronyms of federal agencies, military organizations, titles, and expressions, this book lists aerospace and communications-electronics terms, many of which are interrelated with federal agencies. It also contains the acronyms of thousands of associations, societies, federations, unions, and other nonprofit organizations in the United States. The acronyms of corporations, universities, and transportation facilities are not listed when they are used only locally. Military ranks and acronyms of limited usage are usually omitted.

DIRECTORIES

Interavia ABC: World Directory of Aviation and Astronautics, 1960. Geneva, Interavia S.A., 1960. 1,281 pp. $12.

Although some 2,500 new aviation authorities, organizations, and firms have been added to this eighth edition, the compilers have succeeded in keeping the 1960 volume down to the size of last years edition. This has been achieved by compressing two sections, Who Is Where and Airports—National & Local, and by omitting the section, Private Aircraft Owners.

European organizations (Air Research Bureau, European Civil Aviation Conference, etc.) have so increased in number and significance that they are listed under an entirely new heading, Europe.

The astronautics and electronics sections, which were introduced last year, have been considerably extended. The same applies to the aircraft industries and civil aviation of the Eastern European states, on which more comprehensive information has been received than in earlier years.

ELECTRONICS & ELECTRICITY

Direct Conversion of Heat to Electricity. Edited by Joseph Kaye and John A. Welsh. New York, John Wiley & Sons, Inc., 1960. 365 pp. $8.75.

The volume is an outgrowth of a Special Summer Program offered by the Dept. of Mechanical Engineering, M.I.T., July 6–17, 1959.

Contents: Part A, Thermionic Engines—High Vacuum. 1, Analysis and Experimental Results of a Diode Configuration of a Novel Thermoelectron Engine, G. N. Hatsopoulos and J. Kaye. 2, The Thermionic Diode as a Heat-to-Electrical-Power Transducer, W. B. Nottingham. 3, Thermodynamics of Thermionic Engines, G. N. Hatsopoulos. 4, Prediction of Optimum Performance of Vacuum-Diode Configuration of Thermionic Engines, G. N. Hatsopoulos, J. Kaye, and E. Langberg. 5, Theoretical Analysis of a Magnetic Triode as a Thermionic Engine, J. A. Welsh, G. N. Hatsopoulos, and J. Kaye.

Part B, Thermionic Engines—Low Pressure. 6, Thermionic Energy Converter, K. G. Hernqvist, M. Kanefsky, and F. M. Norman. 7, The Gas-Filled Thermionic Converter, V. C. Wilson. 8, Cesium Plasma Diode as a Heat-to-Electrical-Power Transducer, W. B. Nottingham. 9, Thermionic Power Conversion and Its Possibilities in the Nuclear Field, K. G. Hernqvist. 10, Characteristics of a Plasma Thermocouple, R. W. Pidd, G. M. Grover, E. W. Salmi, D. J. Roehling, and G. F. Erickson. 11, Energy Converter Using Low Pressure Cesium, H. Steele.

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Part E, Fuel Cells. 23, Fuel Cells as Energy Converters, J. F. Yeager.

The Dynamic Behavior of Thermoelectric Devices. Paul E. Gray. Cambridge, Mass.,

The Technology Press of M.I.T.; New York, John Wiley & Sons, Inc., 1960. 136 pp. $3.50

This monograph treats of the dynamic behavior of thermoelectric heat pumps and generators by means of small-signal analysis. This approach permits the treatment of linear models that describe the small-signal dynamic behavior of the devices. The results of this analysis can also be used to evaluate the quantitative effect of the materials and device parameters on the dynamic behavior of devices.

The research reported in this book was conducted while the author was a member of the Energy Conversion Group, Electronic Systems Laboratory, M.I.T.

Photoconductivity of Solids. Richard H. Bube. New York, John Wiley & Sons, Inc., 1960. 461 pp. $14.75.

The purpose of this book is to present a unified picture and interpretation of photoconductivity phenomena, by drawing examples from materials of various kinds, and to show the correlation between photoconductivity and other related photophenomena in insulators and semiconductors. The emphasis throughout is placed on setting forth a physical description leading to a qualitative understanding of photoconductivity rather than on presenting detailed mathematical analyses. There is a comprehensive bibliography of the literature (1,009 references).

Dr. Bube is a senior member of the technical staff of the RCA Laboratories, David Sarnoff Research Center, Radio Corporation of America, Princeton, N.J.

FUELS & LUBRICANTS

Petroleum Products Handbook. Virgil B. Guthrie, Editor. New York, McGraw-Hill Book Co., Inc., 1960. 837 pp. $18.50.

This reference work presents practical information and data that will help oil companies and large-scale users of commercial petroleum products in the efficient storage, handling, and utilization of these products. Among the many petroleum products covered are gasoline, aircraft gas turbine fuels and lubricants, greases, waxes, and petrochemicals. Additives are classified, and their functions are defined. A special feature is a Reference Data Directory, which serves as a quick means for locating published sources for current data on tests and specifications, storage, handling, shipping regulations, etc.

Some thirty specialists contributed to this handbook under the editorship of the former Editor of *Petroleum Processing* and Managing Editor of *National Petroleum News*.

INSTRUMENTS

Basics of Gyroscopes, Vol. 1 and 2. Carl Machover. New York, John F. Rider Publisher, Inc., 1960. Vol. 1, 101 pp. Vol 2, 114 pp. $3.30 per vol.

These books present, for nonspecialists, students, technicians, engineers, salesmen, and managers, a basic explanation of the principles underlying the science of gyroscopics. Volume 1 explains what a gyro is and how it works, the law of gyroscopics and gyroscopic precession, and the mechanics of vertical and directional gyroscopes. Volume 2 concerns itself chiefly with rate and integrating gyros, stable platforms and inertial navigation, and gyro construction and applications. Numerical examples are employed to illustrate the operation of the gyroscope and review questions at the end of each section aid the reader in determining the degree of comprehension of the material previously read.

The author, formerly a Manager of Application Engineering, Ketay Dept., Norden Div., United Aircraft Corp., is presently with Skiatron Electronics & Television Corp.

MATERIALS

Mechanics of Materials. Archie Higdon, Edward H. Ohlsen, and William B. Stiles. New York, John Wiley & Sons, Inc., 1960. 502 pp. $7.75.

In their approach to the primary objectives of a course in mechanics of materials, the authors have followed traditional lines, and the principles and methods used are drawn largely from prerequisite courses in mechanics, physics, and mathematics together with the basic concepts of the theory of elasticity and the properties of engineering materials. The major emphasis is placed on the elastic range of stress, and, where feasible, the presentation is extended to include the analysis of the plastic range of stress with appropriate problems.

The authors are associated, respectively, with the U.S. Air Force Academy, the Iowa State University of Science and Technology, and the University of Alabama.

MATHEMATICS

Mathematical Methods for Digital Computers. Edited by Anthony Ralston and Herbert S. Wilf. New York, John Wiley & Sons, Inc., 1960. 293 pp. $9.00.

Contents: Part 1, Generation of Elementary Functions. (1) Generation of Elementary Functions, E. G. Kogbetliantz.

Part 2, Matrices and Linear Equations. (2) Matrix Inversion and Related Topics by Direct Methods, A. Orden. (3) The Solution of Linear Equations by the Gauss-Seidel Method, R. Van Norton. (4) The Solution of Linear Equations by the Conjugate Gradient Method, F. S. Beckman. (5) Matrix Inversion by the Method of Rank Annihilation, H. S. Wilf. (6) Matrix Inversion by Monte Carlo Methods, F. J. Oswald. (7) The Determination of the Characteristic Roots of a Matrix by the Jacobi Method, J. Greenstadt.

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NAVIGATION

Theory of Inertial Guidance. Connie L. McClure. Englewood Cliffs, N. J., Prentice-Hall, Inc., 1960. 340 pp. $12.

This volume is devoted to a systematized development of the basic theory and elemental configuration of inertial systems employed in stabilization, navigation, and guidance. It opens with a review of the mathematics prerequisite for full comprehension of the subject: Cartesian transformations, the vector concept, some fundamentals of vector analysis, kinematic fundamentals, and certain concepts of rigid body dynamics. The two succeeding chapters are devoted to classical gyrodynamics and the preliminary theory of stabilized platforms. The concluding chapters deal with single-channel descriptions of terrestrial inertial systems, other single-channel descriptions, and terrestrial inertial guidance. Additional data concerning terrestrial celestial navigational variables and computations, control system stability, and miscellaneous mathematical topics are presented as appendixes.

The author is an Advisory Mathematician, Federal Systems Division, International Business Machines Corp.

PHYSICS

Infrared Radiation. Henry L. Hackforth. New York, McGraw-Hill Book Co., Inc., 1960. 303 pp. $10.

An introductory text for use in junior college and university courses, and for those readers desiring background information in the field. The use of mathematics has been reduced to a minimum.

In Part 1, Chapters 1 through 8, the reader is introduced to the fundamental principles of infrared radiation, to the components, materials, limitations, and problems encountered, and to the scope and future possibilities of infrared systems. Chapter 1 describes the nature of infrared radiation and presents a brief history of its development. Chapter 2 defines the basic physical laws and develops a model of a generalized infrared system (used throughout the book) which traces the path of an infrared signal from its source to its final recording or display. Chapters 3 through 7 discuss in detail the "building blocks" used in this model—infrared sources, atmospheric transmission, optical components and systems, optical materials, infrared detectors, and mechanical and electronic techniques. Chapter 8 discusses the fundamental principles of infrared system design.

Part 2 illustrates how these concepts are applied in the fields of astronomy, astrophysics, geophysics, meteorology, and in industry, including aircraft and missiles, atomic energy, and space technology.

The author is a member of the Research Staff, Nortronics Division, Northrop Corp.

Physicochemical Measurements at High Temperatures. Edited by J. O'M. Bockris, J. L. White, and J. D. Mackenzie. London, Butterworths Scientific Publications; New York, Academic Press, Inc., 1959. 394 pp. $13.50.

Contents: 1, General Aspects of Physicochemical Research at High Temperatures, J. O'M. Bockris. 2, Temperature Measurement, J. L. Margrave. 3, Means of Attaining and Controlling Temperature, K. Motzfeldt. 4, The Stability of Refractory Materials, D. T. Livey and P. Murray. 5, Phase Equilibria with Particular Reference to Silicate Systems, J. F. Schairer. 6, Chemical Equilibria, F. D. Richardson and C. B. Alcock. 7, Calorimetry, O. Kubaschewski and W. A. Dench. 8, Liquid Densitometry, J. L. White. 9, Surface Tension, P. Kozakevitch. 10, Vapour Pressure, J. L. Margrave. 11, Electrochemical Measurements, J. W. Tomlinson. 12, Scattering and Absorption of Visible Light in Fused Salts, W. Bues. 13, Ultrasonic Velocity Measurements, N. E. Richards and H. Bloom. 14, Measurement of Diffusivity in Liquid Systems, Ling Yang and M. T. Simnad. 15, Viscometry, J. D. Mackenzie.

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RADARGRAMMETRY

Radargrammetry. Daniel Levine. New York, McGraw-Hill Book Co., Inc., 1960. 330 pp. $12.

Radargrammetry is defined as the science of obtaining reliable measurements by means of radar. Although it encompasses both ground and airborne applications, the latter are emphasized in this book because of their importance in preparing maps from both scanning and side-looking radar equipment.

Using cartographic principles, the book correlates radar display with different map projections and shows how this correlation is applied to map-matching, navigation, air traffic control, weather surveillance, and long-range plotting for air defense, bombing, and missile guidance. It also covers such topics as image motion compensation and antenna stabilization, ground-range sweep over a spherical earth, the theory of radar return, and errors in radar systems influenced by navigational equipment and airframes. The treatment is mathematical.

Before entering private consulting, the author was with the Goodyear Aircraft Corp. as a Senior Specialist working on radar guidance and prediction.

SPACE TRAVEL

Satellites and Scientific Research. Desmond King-Hele. London, Routledge & Kegan Paul; New York, Dover Publications, Inc., 1960. 180 pp. $4.00. 21*s*.

The first half of the book outlines the life-history of a typical satellite and the laws governing its motion, gives details of the satellites already launched and the methods of tracking them, and shows how satellites fit into the general pattern of research. The second half describes the discoveries made about the earth, the upper atmosphere, and the regions of space beyond.

The book is written, as far as possible, in non-technical language. Mathematical formulas are at a minimum; there is a short mathematical appendix and a list of relevant books and scientific papers.

The author is presently a principal scientific officer, Royal Aircraft Establishment, Farnborough.

The Exploration of the Solar System. Felix Godwin. London, Chapman & Hall, Ltd.; New York, Plenum Press, Inc., 1960. 200 pp. $6.50.

This book is an attempt to predict the development of astronautics in the next 150 years. Expeditions are planned in detail in order to demonstrate not only how problems of space travel might be overcome, but also how they might be surmounted with equipment available or forseeable today. The cost of such expeditions is estimated.

An important aspect of the work lies in the author's distinction that the means of getting to other planets should not be confused with the ends of space travel; therefore a large proportion of the book is devoted to a discussion of what explorers would do when they arrive on the Moon, Venus, and Mars.

STRUCTURES

Structural Mechanics. Samuel T. Carpenter. New York, John Wiley & Sons, Inc., 1960. 538 pp. $9.50.

Emphasis is placed on the mathematical treatment of structural theory bearing on indeterminate structures, and on the introduction of topics from advanced mechanics of materials. Topics in the latter category include finite difference approximations, Fourier series, structural dynamics, and stability. Included also is a brief presentation of Newmark's numerical method for deflections and buckling. The subject of beam columns is considered, and the modifications of moment distribution for axially loaded members are developed.

The author is Chairman, Civil Engineering Department, Swarthmore College.

Personnel Opportunities

This section is for the use of individual members of the Institute seeking new connections and eligible organizations offering employment to specialists in the aerospace industry. Any member or eligible organization may have requirements listed without charge by writing to the Secretary of the Institute.

Wanted

Engineers—Staff positions now open for graduate design and development engineers with experience in application engineering, performance design, thermodynamic design, aerodynamic design, heat transfer, evaluation, compressor design, turbine design, lube systems, rotors, rocket engine development. Full benefits, including tuition refund. Promotion-from-within and merit review policies assure advancement commensurate with professional development. Write fully to Mark Peters, Dept. 2, Bldg. 100, Flight Propulsion Division, General Electric Co., Cincinnati 15, Ohio.

Flutter and Vibration Engineers—M.S. in A.E., Physics, Applied Mechanics, or related engineering field, with minimum of 5 years' experience in aeroelasticity, vibration, or flutter. Applicant should have strong theoretical background in unsteady aerodynamics, structural response, and applied mathematics; or alternatively, practical experience in dynamic model design and testing, aircraft vibration, and flight flutter testing. Openings also exist for senior engineers in analog simulation of flutter and structural dynamics problems. Previous experience or training is desired, with knowledge of the Direct Analogy Electric Analog (DAEAC) particularly valuable. **Dynamics Engineers**—B.S. or M.S. in Engineering, Physics, or Applied Mechanics. Applicants with experience in vibration, transient dynamic problems, structural analysis, analog or digital simulation methods, needed for work on advanced aircraft, missile and space vehicle applications. Salary range commensurate with educational background and previous experience. Send detailed résumé of technical qualifications to H. W. Schultz, Professional and Technical Placement Group, Lockheed Aircraft Corp., Georgia Division, Marietta, Ga.

Aeronautical Engineering—Qualified engineers interested in teaching positions with the aeronautical engineering department of a new and rapidly growing institution are invited to make inquiries. Practical industrial experience is preferred to advanced studies. Please send a résumé of teaching or industrial experience and desired teaching areas to the Dean of Engineering, California State Polytechnic College, Pomona, Calif.

Professor or Associate Professor—To teach courses in aero/space engineering at both undergraduate and graduate levels and direct graduate research. Advanced degree required. Salary and rank dependent upon qualifications. Address inquiries and send personal data to E. W. Anderson, Head, Department of Aeronautical Engineering, Iowa State University of Science and Technology, Ames, Iowa.

Research Engineer—Ph.D. or M.S. in M.E., Ch.E., or C.E. Expanding technical development organization offers unusual opportunities for person with primary interests in fluid mechanics, non-Newtonian flow, and multiphase flow. Send detailed confidential résumé to Shell Pipe Line Corp., P.O. Box 2648, Houston 1, Tex.

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